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GLACIAL FEATURES OF THE ALASKAN COAST BETWEEN YAKUTAT BAY AND THE ALSEK RIVER[1]

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Since the pioneer studies of Russell, Reid, and Muir among the glaciers of southern Alaska, the extension of exploration has gradually brought more and more of them within the range of observation, until now most of the more important have been located and a few of them carefully described. The ice-fields of the St. Elias region are among the most interesting of these, and, thanks to the researches of Russell, Gilbert, Tarr, and Martin, are among the best known. It was my privilege in 1906 to explore portions of the coast immediately east of the field studied by these men. The present paper is presented in order to record for the first time[2] the glacial features of that strip, and to form the basis for the further exploration and comparative study which is sure to come in later years.

From Yakutat Bay to the Alsek River the outer coastal mountains, for which I propose the name Brabazon Range,[3] is separated from the

[1] Published by permission of the Director of the U. S. Geological Survey.

The accompanying map has been redrawn and adapted from the field map prepared in 1906 by my associate in the field, Mr. A. G. Maddren. Certain additions are based on photographs and surveys by Mr. A. J. Brabazon, of the Canadian Boundary Survey.

[2] Previous maps show the position of the larger glaciers, but no description of them has been given.

[3] From A. J. Brabazon, of the Canadian Boundary Survey, who in 1895 made the first topographic map of these mountains. The range begins at the lowest

Pacific by an alluvial coastal plain. On the east side of Yakutat Bay low morainic deposits, densely wooded, slightly relieve the general flatness, and along the mountain front low rocky knobs rise to a height of 100 feet or more. Aside from these exceptions, the plain has the monotony of a delta surface. Much of it is covered with dense spruce forests; but wide tracts are kept bare by the floods[1] of such rivers as the Dangerous and the Alsek, and by the tides, as at the mouth of the Italio; while swamps and wet mossy prairies occupy large irregular areas farther inland.

The Brabazon Range is low as compared with the lofty peaks west of it; but nevertheless it is a notable feature of the coast. It has a steep seaward front, which, although somewhat irregular in outline, plunges abruptly beneath the alluvial flat without extensive foothills or projecting spurs. One depression interrupts the continuity of the ridge in the area discussed—the open channel of the Yakutat Glacier. The highest peaks of this range are Mount Unana (6,000 feet) and Mount Ruhamah (5,600 feet[2]) on the east side of Russell Fiord, together with Mount Reaburn[3] (5,300 feet) and its nameless neighbors east of the Yakutat Glacier. Within the mountains the topography is buried under a thick mantle of ice, through which isolated mountains protrude—"a land of nunataks," as Russell has aptly described the country about Mount Logan.

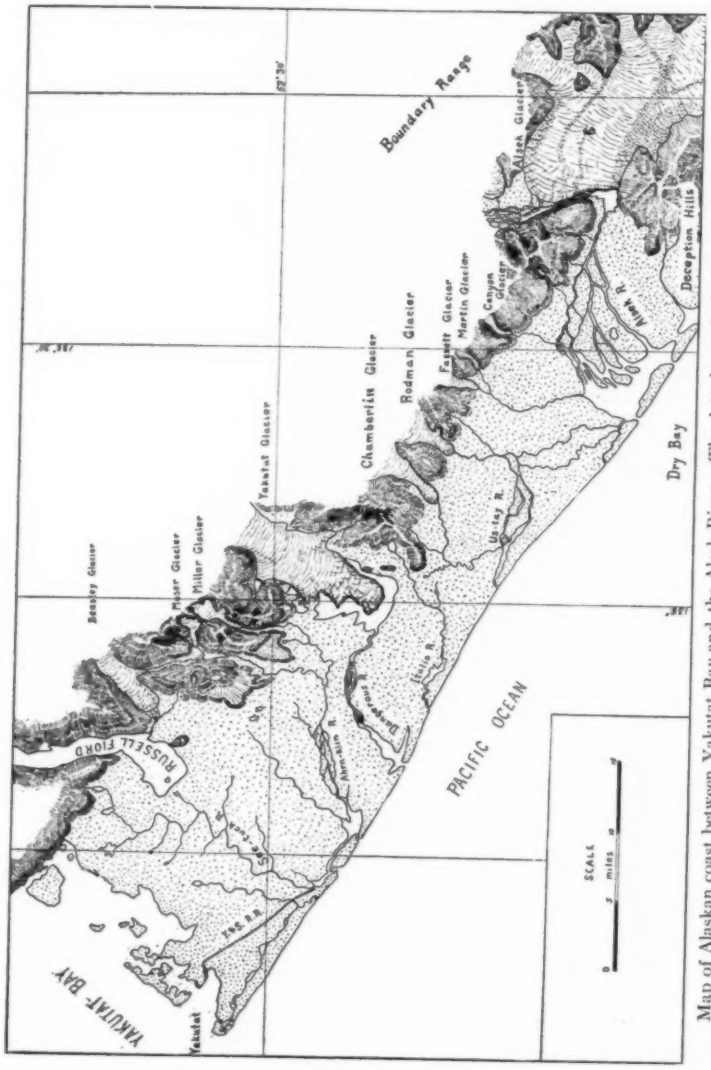
The only large river of the region is the Alsek—a powerful stream which rises in the plateau north of the mountainous belt and trenches the uplift in a series of wild canyons which have a total length of

canyon of the Alsek River and fronts the foreland northwest as far as Russell Fiord. It is separated from the inner ranges largely and perhaps wholly by broad ice-fields. Structurally it seems to be continuous with the Puget peninsula on the northwest and Deception Hills on the southeast, but it is separated from them by the fiord and river mentioned.

[1] For an example of similar devastation by the Yatse River, see Russell "Second Expedition to Mt. St. Elias," U. S. Geological Survey, *Annual Report. XIII*, p. 60.

[2] Elevations taken from maps of the Canada-Alaska Boundary Award (based on Brabazon's survey of 1895).

[3] This peak is named in honor of Mr. W. B. Reaburn, who, as a member of the U. S. Boundary Survey Party in 1906, was the first white man to cross the Yakutat Glacier, from the surface of which this peak is a conspicuous landmark. The mountain is situated approximately in latitude 59° 26½′ north and longitude 138° 38½′ west, and is the first high peak east of the Yakutat Glacier. (See Fig. 3.)



Map of Alaskan coast between Yakutat Bay and the Alsek River The dotted area is the coastal plain; the larger glaciers are shown by the broken lines, with moraines dotted, while the little cliff-glaciers are represented by the black.

about 110 miles. Majestic glaciers descend into it at several points on either side, contributing their load of detritus to its turbid current. Eventually it emerges from its canyon through the outermost or Brabazon range and spreads out in shifting channels over a broad, gravelly delta. At the time of our visit there were three main distributaries at the head of the delta, which anastomose with each other to some extent below. An abandoned moraine of the Alsek Glacier checks the river temporarily as it leaves the canyon, and thus forms a small but deep lake at the elbow of the sharp bend. Icebergs of all sizes are constantly breaking off from the end of the glacier. Some lie stranded on the shelving shores of the lake, while others gradually drift into the current of the outlet and are thence whirled out upon the delta. All melt before reaching the Pacific.

The coastal mountains of this part of Alaska are still, like Greenland, in their glacial period. All the principal valleys are clogged with ice, and only the smaller gulches are without glaciers. The glaciers vary in size from mere snow-fields which have a slight motion, to great plateaus of ice, scores of square miles in extent. The front of the Brabazon Range affords eight or nine glaciers of considerable size, in addition to the Alsek Glacier which lies to the west, and the numerous little cliff-glaciers which are found in the lateral ravines. Some of these larger lobes we observed only from a distance, but others were examined in some detail.

We may now take up the consideration of the several glaciers individually, beginning where Russell and his successors left the work, and carrying the chain with varying detail as far as the Alsek. The first in order is the Beasley Glacier,[1] a lobe which joins the sources of the Hidden Glacier across a snow-filled pass and thence descends southwestward on the east side of Russell Fiord. This we saw only from the mountain spur east of it. Its clear white surface is striped with two or more distinct moraines. Sloping gradually downward, it ends in a barren outwash-flat composed of gravel and bowlders.

[1] This glacier is generally known to the people of Yakutat as the "Fourth Glacier," but as there is no logical starting-point in enumerating the glaciers by number in such a way as to make this the fourth, it seems advisable to give this large and conspicuous lobe a definite name. For this reason, it is proposed to call it the "Beasley Glacier," in recognition of the valuable services which have been rendered to every explorer, who has visited the Yakutat region since the eighties, by Mr. R. W. Beasley, of Yakutat.

FIG. 1.—Terminus of the Moser Glacier, with snow-bank glaciers upon the slopes behind. Taken from the crest of the moraine.

The water discharged issues in several streams, but these combine in a recent cut through the encircling morainic ridge and reach the fiord as a single river.

The Moser valley contains two considerable tongues of ice and several little cliff-glaciers. At the extreme head of the valley a short triangular lobe overflows from the adjacent Beasley Glacier, while a somewhat larger glacier occupies the tributary canyon which joins the main valley from the eastward. The latter we take to be the Moser Glacier.[1]

The triangular lobe from the Beasley Glacier is smooth and white. At its terminus there is no distinct moraine, nor is there any considerable amount of débris upon the end of the ice itself. A level outwash train of coarse gravel trends away from the glacier down the valley.

The Moser is an excellent example of the small alpine glacier. If its snow-fields are included, it is about 2½ miles long, the bare icy portion being about 1½ miles in length. The width of the cirque is nearly 1½ miles, but the glacier itself has a constant width of slightly less than half a mile. It lies in a deep canyon, the walls of which rise steeply to heights of 1,500–2,000 feet, and then more gently to summits about 2,000 feet higher. The cirque is filled with snow and névé which is slightly crevassed. Lower down the transverse crevasses become much more numerous and the clear ice makes its appearance. About a mile from the lower end, the angle of slope becomes much gentler, the crevasses less numerous and radial rather than transverse in direction, and the surface is comparatively smooth. At the time of our visit it was not difficult to cross the lower part of the glacier in almost any direction, provided one paid due regard to the many, although narrow, cracks. On each side of the lower end of the tongue the ice is covered with débris which stands out upon the surface in relief, forming two lateral moraines. A medial moraine makes its appearance suddenly three-tenths of a mile from the end, and is a prominent feature of the nose of the glacier. Its origin is not obvious. At no distant time the Moser Glacier has been three-

[1] Lieutenant Hugh Rodman, of the U. S. Fish Commission, passing along the front of the foreland in 1901, observed that this valley contained a glacier, and, supposing doubtless that it was a single tongue of ice, he named it the Moser Glacier. In 1906 we found two distinct glaciers in this valley, and have applied to the larger of them the name proposed by Lieutenant Rodman.

tenths of a mile longer than at present, and simultaneously probably several hundred feet thicker. This expansion is clearly recorded by a bowldery moraine which encircles the mouth of the canyon and is attached to the rocky walls on either side by a gradually diminishing lateral moraine, or moraine-terrace, which now stands at a considerable elevation above the glacier. The abandoned space inside the moraine is a bowldery waste devoid of vegetation. The outer part of the moraine itself, however, is forested with spruce, and its hummocky topography is thereby obscured.

The little cliff-glaciers of this valley which have been mentioned are of various sizes and are about four in number. Three of these occupy the southern slope of Crescent Mountain.[1] They are steep, cascading glaciers which are plastered in the heads of the shallow gulches. The fourth, which lies upon a gentler slope south of the Moser Glacier, is irregular and roundish in outline. It is noteworthy that no glaciers exist on the northeast slope of Slate Peak.[2]

The next valley to the eastward, drained by another branch of the Ahrn-klin River, contains one glacial lobe and several little snow-bank glaciers. Its cirque affords an ample gathering ground for snow, and is separated from the head of the Moser Glacier on the west by a sharp arrete. The tongue of ice itself is somewhat longer and narrower than its neighbor, being about 2¼ miles long and about one-fourth of a mile wide. The lower end is black with moraine-stuff, and frequent avalanches from the steep walls of the canyon keep the sides dirty with similar débris.

The Miller Glacier appears to have a surface much like that of its western neighbor, but even less crevassed. It shows no evidence of recent advance and is not surrounded by a distinct moraine. Miller Creek issues from the end of the glacier and flows over a barren, gravelly valley-train out to the foreland.

The little cliff-glaciers of this canyon are few in number. We noted but one on the west side of the valley, and that at an elevation of 3,000 feet. On the east side three or four little bodies of ice occupy hollows in the lee of the mountain crest.

[1] So named from the crescent-shaped syncline of gray rock visible in its summit. It lies immediately north of the Moser Glacier.

[2] In 1906 Mr. Thomas Riggs, Jr., applied this name to the peak which separates the Beasley Glacier from the Moser valley.

The open gap which interrupts the Brabazon Range midway in its course is partially filled by the broad Yakutat Glacier. This is merely a lobe descending from the interior ice-fields, not an alpine glacier of the type illustrated by the Moser and Miller lobes. The descent of the Yakutat Glacier is gradual throughout, but at several places there are steeper declivities, more crevassed, which approach the character of ice-falls. The length of the glacier after it leaves the parent ice-field appears to be about 12 miles. Its average width is

FIG. 2.—The Miller Glacier. A short alpine glacier descending from the snows of a capacious cirque.

3–4 miles, but toward the end it becomes ragged in outline, and the width decreases to 2½ and finally to 1½ miles. So far as observed, the surface of the ice is badly crevassed, especially near the terminus. There the ice is broken by great cracks, some of which admit the water of the lake far back into the glacier. Four or 5 miles back from the end, and especially along the margins of the glacier, there are, however, certain stretches which are moderately smooth and may be traversed without notable difficulty. The Yakutat Glacier lacks the prominent

FIG. 3.—Surface of the Yakutat Glacier. On the left is the gap in the range through which the lobe finds exit from the inner ice-fields. The snowy cloud-wrapped peak to the right of the center is Mount Reaburn.

trains of débris which lie upon the surface of almost all the other glaciers of the region.

The lower end of the glacier is encircled from mountain to mountain by a crescent-shaped moraine more than a mile wide, which rises but a few score feet above the foreland. It has the characteristic knob-and-kettle topography of terminal moraines in general, contains numerous small lakes and swamps, and is strewn with bowlders. The till consists largely of rocks of the Yakutat series (early Mesozoic?), with the addition of many crystalline schists and intrusives from the older formations. One of the most conspicuous varieties represented in the large bowlders on the moraine is the coarse graywacke-conglomerate of the upper portion of the Yakutat series.[1]

Between the inner edge of the moraine and the ragged border of the glacier lies a long, irregular lake, to which we have given the name Harlequin Lake.[2] The water is muddy with the rock-flour derived from the glacier. Occasionally during the day the crash of icebergs falling into the water may be heard, but disintegration here is much slower than it is along the front of the Alsek Glacier. The water of the lake is now discharged through a cut in the moraine and makes the Dangerous River. On the borders of the lake and the surface of the moraine there is evidence that the lake waters have recently been much higher than at present, and that they have not always used the same exit as at present. A series of well-marked and unmutilated wave-built terraces encircles the lake on the moraine side at various elevations up to 100 feet above the present surface of the water. About a mile north of the present Dangerous River the moraine is intrenched by two dry outlet channels, which converge and join before reaching the outer edge of the moraine, so that they issue in a single channel. The channels are bare and strewn with gravel and bowlders. They are from 60 to 100 feet deep, and the bottoms

[1] The outer front of the moraine is bordered by an extensive outwash-plain. Near the foothills on the west this plain slants perceptibly outward from the moraine, while nearer the Dangerous River the declivity is hardly perceptible. Shallow dry channels furrow the outwash at several places. Near the moraine the normal flood-plain of the Dangerous River is about 30 feet below the plain, but 5 miles nearer the ocean the difference is scarcely 5 feet.

[2] Named from the fact that a pair of harlequin ducks were the only living things seen upon it.

were about 40–50 feet above the surface of the lake in 1906. The fact that vegetation has not invaded these channels suggests that they are of very recent origin, and this inference is borne out by the freshness of the loose terraces bordering the lake. It is suggested that the Dangerous River outlet may at times become so clogged with icebergs as to form a dam, and that the level of the lake is therefore subject to fluctuations. This may perhaps explain the reputation for disastrous floods which the river has among the natives of the Yakutat

FIG. 4.—Shattered side-lobe of the Yakutat Glacier. Shows the scarp and the mass of freshly broken ice which resulted from the collapse in 1906.

foreland; for the breaking of such an ice-dam would liberate suddenly a large volume of water.

Tributary valleys coming in from the southeast and northwest have been obstructed by the glaciers, and thus several marginal lakelets have been produced. On the west side of the glacier we observed at least four of these blockaded lakes. The uppermost and largest one was found completely filled with a mass of clear broken ice and held in by a much-crevassed scarp of ice about 200 feet high.

Evidently the lake was formerly covered by a glacial lobe which has since collapsed. The extreme recency of the occurrence is indicated by the fact that many blocks of ice lie stranded upon the rocky sides of the valley 50–100 feet above the water, thus marking the original level of the glacier. As such detached fragments usually melt quickly in the mild summer months, it can hardly be doubted that the collapse took place in 1906. The lowest of these lakes discharges its waters into the terminal lake through a cascading brook. The higher lakes, however, must have subglacial outlets; much water is poured into them by streams from the adjacent slopes, yet there is no exit for this upon the surface. It seems probable that the subsidence of the ice in the uppermost lake was caused by an unusually rapid removal of water through such a subglacial channel.

The Yakutat Glacier receives no considerable tributaries from the mountains on either hand. A few snow-fields and a few diminutive glaciers occupy the heads of the gulches on both sides, particularly in the valley which contains the shattered ice above mentioned, but these do not reach the bottoms of the valleys.

Of the glaciers between the Yakutat and the delta of the Alsek, as well as on the west side of the Yakutat Glacier itself, I can give only brief mention. Our route lay too far from the mountains to permit us to see them in detail. The Chamberlin, Rodman, and Fassett are all large alpine glaciers, and all extend out upon the edge of the foreland. On previous maps they are represented as being lobes of the inner ice-plateau, but the view from the foreland gave no confirmation of this. Although the upper reaches of the glaciers are hidden by the turnings of their canyons, and thus it is not possible to see directly whether they come through the rock divide, it is significant that they have steep descents, which are much more characteristic of the isolated valley glaciers than of the large "through" lobes.

Two smaller glaciers lie east of the Fassett. One, the Martin[1] Glacier, is a rather narrow tongue like the Miller and descends nearly to the level of the plain. Its companion on the east is of similar size, but does not descend as low. It derives its name from the fact that it is sunk deep in a canyon, the walls of which are remarkably

[1] After Mr. E. R. Martin, who was in immediate charge of the U. S. Boundary Survey Party which surveyed this portion of the range in 1906.

FIG. 5.—The Alsek Glacier as seen from the end of the Brabazon Range. The boundary range in the rear culminates in Mount Fairweather on the right. In the left middle is the Green Nunatak with its medial moraine. The extreme left of the glacier is not shown in the picture. The canyon of the Alsek River is hidden by the spur in the foreground. (Photo by Brabazon, Canadian Boundary Survey, 1906.)

precipitous and continuous. The lower end of the glacier is smooth and dirty with the débris of avalanches from the cliffs above. Doubtless the absence of notable crevasses here is to be ascribed to the fact that the ice is closely confined down to its very end, and hence the tension which would result from an unrestrained deployment is lacking.

From the Canyon Glacier east to the Alsek River no glaciers of considerable size remain. The heads of the gulches have been glaciated, as is indicated by the well-developed cirques and the rock-bound lakes; but only very small snow-bank ice-fields now remain.

The Alsek Glacier is the largest of all in the area of our survey. It heads on the west slope of Mount Fairweather, and, after receiving many icy tributaries from the Boundary Range north of it, eventually reaches and constricts the Alsek River at its lowermost canyon. The lower part of the glacier is a great, flat ice-field or plateau having a breadth of 6–7 miles from northwest to southeast, and somewhat more from northeast to southwest. The main body of the glacier comes in from the east just behind the Deception Hills. Two broad tributary tongues enter southeast of the Green Nunatak,[1] while a third, which is double, comes down from the boundary range some distance farther to the north. Each of these tributary glaciers would in most regions be considered large by itself. The influence of the great lobe from Mount Fairweather seems at present to be slight, as is evidenced by the fact that the south side is not bulged northward at the junction. Much of the ice is clean and white, but a number of medial and lateral trains of dirt blacken it in places. Apparently by the slow spreading of the glacier itself, these moraines have widened and even coalesced in their lower courses. Different parts of the glacier show wide variations in the amount of crevassing which they have suffered. In general, the steeper parts of the tributaries are much cracked. Of the open plateau-like expanse at the end, the northern part is not much crevassed, and its level surface may be traversed safely if ordinary care is used. The cleaner part, south of the Green Nunatak and Gateway Knob, is a bristling mass of sharp seracs with deep crevasses between. It would be very difficult, and

[1] This name is applied in recognition of the fact that the medial moraine which originates in this nunatak consists chiefly of green slate fragments.

FIG. 6.—The lowest canyon of the Alsek, from within. On the left are the Alsek Glacier and the Deception Hills; on the right, the inner slope of the Brabazon Range, with four of its many little glaciers. The overloaded Alsek in the foreground is a typical glacial river. (Photo by Brabazon, Canadian Boundary Survey, 1906.)

probably impossible, to cross this portion of the glacier without going far eastward to the foot of the mountains.

On the northwest border the glacier descends gradually to the alluvium which bounds it on that side. Where the glacier reaches the river itself it has a vertical front 4 miles in length, which is interrupted only by the rock hill (called Gateway Knob) at the mouth of the canyon. To the north of this hill there appears to be little movement in the glacier, as bergs drop off only infrequently.

FIG. 7.—Front of the Alsek Glacier. Dirty portion north of Gateway Knob, showing the horizontal stratification of the ice.

South of the rocky knob the front shows the beautiful blue-green color characteristic of freshly broken clean ice. Large masses of ice, usually the blocks between crevasses, break off from this front with thunderous crashes on an average of more than once an hour during the summer. The front itself is nearly 200 feet high, but even these huge masses of ice disappear completely beneath the water into which they fall, and then bob up from below and float away down the river. This indicates that the depth of water along the front is very great.

From the southern end of the frontal cliff a heavy deposit of moraine extends out in the form of a broken loop. The river is actively cutting into this deposit of till and seems to have destroyed a considerable part of it. The remainder forms a hook-shaped barrier on the south side of the river and sufficiently retards the current to form the Alsek Pool. This bulb-shaped expansion of the river at the mouth of the canyon is nearly 2 miles in diameter, and but for the gravelly plain on the north would be nearly square. On the north side of the

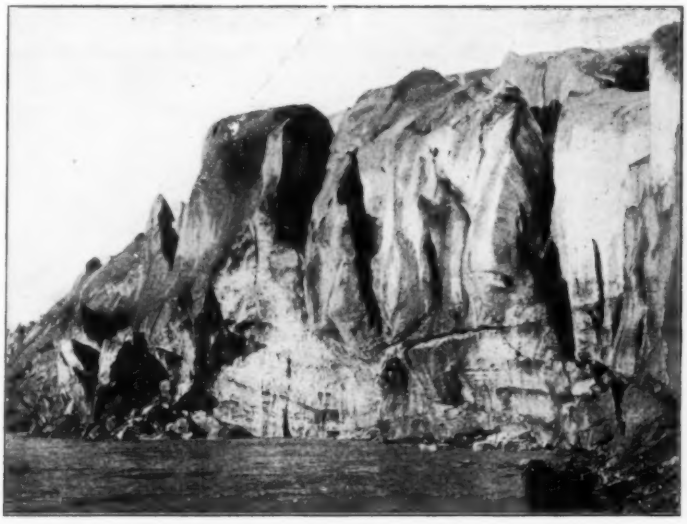


FIG. 8.—Front of the Alsek Glacier. Vertical cliff of dirty ice 160 feet high continually undermined by the river.

river the complement of the moraine ridge has not been identified. In spite of the powerful current poured into it by the Alsek the surface of this lake is nearly still. The bergs which fall from the glacial scarp drift very slowly down toward the exit from the lake. Sometimes they become stranded on the shallow north beach, where they are broken up by the waves and melt. At times those which succeed in reaching the exit congregate there in such masses that the channel becomes congested with them, and the river is temporarily

raised until sufficient force is accumulated to sweep out the obstruction. Sudden rises of as much as 6 feet, which we noted at the mouth of the canyon, are attributed to this condition.

Within the valley of the Alsek, above the lowest canyon, numerous glaciers of all sizes line the slopes on both sides. All the valleys are filled with huge lobes of ice. The smaller canyons have steep mountain glaciers, and scarcely a ravine in the higher mountains is without its little glacial tongue (Fig. 6). But this by itself is another story which is still too imperfectly known to be presented at this time.

Among the glaciers which have been described in the preceding pages we may readily distinguish four types. In the cirques and ravines high up in the mountains there are many little cliff-glaciers which are often no longer than wide, and are usually steeply inclined. The majority of them lie more than 2,500 feet above sea-level. In the larger canyons, valley-glaciers of the alpine type are found. These are tongues of ice usually several miles in length, fed by ample snows in the gathering grounds at their heads. The Miller and Canyon Glaciers are good examples. To another type, exemplified by the Yakutat and perhaps the Beasley, Tarr has applied the name "through glaciers,"[1] meaning the great lobes which protrude outward from the inner ice-plateau through gaps in the mountains. These are characteristic of the Yakutat-Alsek region, and are apparently numerous in the upper valley of the Alsek River. They are all large. The fourth type includes the great plateau-like sheets of ice which Russell has called "piedmont glaciers." They are fed by alpine glaciers from various directions and are among the largest glacial features of the region. The Alsek Glacier exemplifies this group.

One of the questions of interest with reference to all glaciers relates to their fluctuation in size. It is needless to say that, during the previous geologic epoch when all the glaciers of North America were greatly expanded, those of the Brabazon Range responded in the same way to the general causes of increase. Since that time they have retreated to fractions of their former lengths and have been reduced in thickness by 2,000 feet or less, according to their sizes and the con-

[1] Tarr and Martin, *Bulletin of the American Geographical Society*, XXXVIII (1906), p. 149.

figuration of their valleys. Changes within the past century are less well indicated.

The subject of glaciation should not be left without a statement regarding the recent changes in the glaciers. In this region no earlier measurements or surveys of sufficient accuracy have been made, and we are therefore without precise data. The fact that each of the glaciers examined is bordered at its end by a terminal moraine, which is separated from the ice itself by a barren space, indicates that the lobes have recently retreated through distances varying from one quarter of a mile to one mile. The Yakutat Glacier is bordered by a lake, and the end of the ice is so badly broken as to give one the impression that it is disintegrating in a condition of relative stagnation. It is obvious at least that none of these glaciers is now actively forwarding its lower end. In no case did we find glaciers plowing up forested moraines and showing other unmistakable signs of advance, such as Tarr reports of the Malaspina.[1] It will be a matter of much interest to watch these glaciers east of Yakutat Bay, and see if they follow the example of the St. Elias lobes, or whether they evince no sympathy with them. This will go far toward solving the question as to whether the advance of the Malaspina is due to a local cause or to some general climatic influence.

[1] R. S. Tarr, *Science*, N. S., Vol. XXV (1907), pp. 34–37.

STRATIGRAPHY AND STRUCTURE OF THE PARK CITY MINING DISTRICT, UTAH[1]

J. M. BOUTWELL

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INTRODUCTION

The Central Wasatch supplied evidence for important principles to the pioneer geologists, and valuable data to succeeding investigators, and now, in the light of recent detailed studies, is proving to be a most fruitful geologic field. It was thus the source for epoch-making writings on orogeny by King and Emmons; for significant observations on the relations of certain igneous masses to sediments by Geikie; for the determination of striking facts of pleistocene geologic history by Gilbert; and for important contributions by other geologists.

The first detailed geologic mapping in this historic region was undertaken in August, 1902, in connection with an investigation of the geology and ore deposits of the Park City Mining District. This was continued through the field season of 1903 and completed in 1904. As a necessary preliminary, broad comparative studies of the geology of the range north and south of the immediate area under survey were made, and standard sections, notably one which was unusually well

[1] Published by permission of the Director of the U. S. Geological Survey.

exposed in Big Cottonwood Canyon, were carefully measured and critically studied. Among the results secured is the precise definition of several stratigraphic formations, including one carrying a previously undescribed Permian fauna; also the solution of several faults of large offset which bear significantly upon mining operations.

Three brief progress reports have been published. The complete statement of the results of that investigation will go to press this year in the form of a "Professional Paper" of the United States Geological Survey. It seems desirable, however, that certain results should be made public at once. This paper has therefore been prepared by request for the purpose of introducing the names of certain stratigraphic formations for the use of writers on these formations in adjacent regions, and of rendering the broad, structural results of the work available for use by local operators.

In this connection it is a pleasure to acknowledge the valuable contributions toward these final conclusions. Thus, the investigation has throughout been under the general supervision of Mr. S. F. Emmons, and in the first year was carried on jointly by Dr. J. D. Irving and the writer, and during the remaining two years benefited by the service of Mr. L. H. Woolsey. Dr. T. W. Stanton has identified the fossil collections from the Jurassic and Triassic, and also in 1903 kindly co-operated in the field in the solution of special problems of stratigraphic correlation; while Dr. G. H. Girty has determined the fossil collections from the Carboniferous, numbering over 100 distinct lots, and throughout the investigation has given helpful interpretations of paleontological evidence. The writer began his work in the region in October, 1900, when it was his good fortune to discover material proof that the main Little Cottonwood granite mass is intrusive in quartzite of Cambrian age, and that the Alta granodiorite body is intrusive in limestone of Pennsylvanian age.[1] In addition to the detailed study of the immediate Park City District throughout the period of survey, he has also carried on comparative studies in stratigraphic correlation and general geology in adjoining portions of this range and the Uintas.

[1] S. F. Emmons, "Little Cottonwood Granite Body of the Wasatch Mountains," *American Journal of Science*, Vol. XVI (August, 1903), pp. 139–47. J. M Boutwell, "Progress Report on Park City District, Contributions to Economic Geology 1902," U. S. Geological Survey, *Bulletin, No. 213* (March, 1903), p. 36.

GENERAL GEOGRAPHY

The Wasatch Mountains, in their middle course, lie in the eastern part of Utah. They are a lofty, rugged range trending northerly and southerly between the Great Basin on the west and the mountainous plateau regions on the east. From a ragged serrate divide on sharp, ledgy peaks 10,000 to 11,000 feet high, the western slopes fall off abruptly 5,000 to 6,000 feet by a wall-like front of striking steepness to the desert below; while the eastern slope, in marked contrast, gives way gradually to upland ranges, plateaus, and high-lying meadows. This unsymmetrical range may thus be compared to a mammoth step several thousand feet in height from the Great Basin on the west to the highlands which extend from its upward portion eastward. These western slopes are interrupted by deep, narrow, rock-walled canyons, through which the drainage from the uplands and parks escapes westward to the desert. The portions of the western wall which lie between these canyons show a marked type of dissection which is characterized by ravines that rise from the level of the desert with steep sides and bottoms, and fork symmetrically upstream repeatedly. The topography in both its larger and smaller features, showing rugged, precipitous slopes, deep, narrow canyons with ungraded bottoms and side cataracts, is indicative of the youth of this range.

GENERAL GEOLOGY

The rocks which form the range are sedimentary, metamorphic, and igneous. The Wasatch sediments, as concisely described by King,[1] are made up of four great divisions, a purely detrital series of Cambrian age, a great limestone extending from Cambrian to the top of the lower Coal Measures, a body of pure siliceous detritus of upper Carboniferous age, and a fourth body of limestone of upper Coal Measure age. The metamorphic rocks include the early regionally metamorphosed sediments and the locally altered or contact metamorphosed rocks. Beyond the fact that these great metamorphic series are pre-Cambrian, their age is unproved, though they are known to be the oldest rocks in the Wasatch. The igneous rocks include several large granitic and porphyritic intrusives and extensive flows.

[1] Clarence King, *Geological Exploration of the Fortieth Parallel Survey*, Vol. I, pp. 100, 101.

The ages and relationships of some of these masses have not yet been completely established.

Structurally the Wasatch Range is a composite, orographic unit. In the largest conception, it is a linear north-south anticlinal range, truncated on the west and probably south by great faults. This major structure is made up of four parts: (1) the Logan syncline, pitching north; (2) the eastern limb of an anticline, constituting the western rim of a Tertiary basin; (3) in the middle part (*a*) a narrow easterly-westerly syncline and (*b*) an easterly-westerly anticlinal dome; (4) to the south the eastern limb of a north-south syncline, probably truncated south of Mount Nebo by a great northeast-southwest fault, with the downthrow on the southeast. These larger structures are exceedingly complicated by several systems of intricate faulting.

The greatest geological activity in the Wasatch Range was in the middle portion at its junction with the great east-west Uinta Range. Extensive and irregular intrusion, widespread extrusion, thorough contact metamorphism, persistent and recurrent faulting, and glaciation have produced in a comparatively small area highly varied and complex geology. At the heart of the area in the focus of these combined factors have been formed the most extensive and richest ore bodies in the range.

This limited area, about 24 square miles, is known as the Park City District. It lies about 38 miles southeast from Salt Lake City, and embraces in its southwest corner the main divide of the Wasatch (Clayton Peak, 10,728 feet), and a prominent spur descending eastward 4 to 5 miles to high-lying interior valleys. The spur separates the area into three natural topographic divisions, which accord with the rock and structural divisions—namely, the north and northwestern slopes, the eastern slopes, and the southern. In the northern and northwestern portions the complete sedimentary sequence is present, dipping universally to the northwest at a moderate angle. On the eastern slope the same formations occur (with noteworthy variations), dipping in general easterly, much faulted, and intruded by irregular stocks and dikes, and on the northeast partly buried by an extrusive mass. The southern portion embraces the great laccolithic stock of diorite in Clayton Peak on the southwest; dikes and stocks of andesite porphyry cutting upward into the overlying sedimentary formations;

and a great east-west zone of contact metamorphosed sediments. It is these metamorphosed rocks which thus hardened stand up as the backbone of the region, the divide between north and south drainage, and form the home of all the great bonanza ore bodies of the district.

STRATIGRAPHY

GENERAL DESCRIPTION

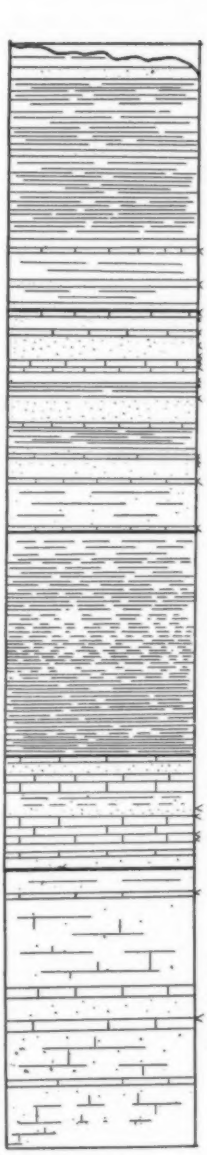
The sedimentary rocks within this district are of Carboniferous and Triassic ages. They are divisible on paleontologic and lithologic evidence into five formations. The lowest (oldest) comprises the upper part of the Weber quartzite, which yields a Pennsylvanian (upper Carboniferous) fauna. Overlying this quartzite is the Park City formation of limestone and sandstone, the former bearing Pennsylvanian fossils. Next above is the unfossiliferous Woodside shale, which is succeeded by the Thaynes formation. The limestones in this formation yield a new fauna resembling both Carboniferous and Permian, considered of "Permian age." The highest beds in the district are the unfossiliferous shales constituting the lower part of the formation which passes upward a few miles northwest of this area into the Triassic sandstone, and thence into the Jurassic limestone.

WEBER QUARTZITE

Name.—About 30 miles due north from Park City and 1 or 2 miles west from Croydon station, the great gray quartzite of the Wasatch section forms both walls of Weber Canyon. "It is from the characteristic occurrence of this remarkable bed of quartzite that the name 'Weber quartzite' has been given to the body" by the geologists of the Fortieth Parallel Survey.[1]

Critical paleontologic and stratigraphic studies lead to the conclusion that the great quartzite of the Park City district is the stratigraphic equivalent of the Weber quartzite in Weber Canyon. Accordingly the name "Weber" will be extended to apply to this formation in the Park City district. Locally it has been known, after the famous mine which lies in it, as the "Ontario" quartzite.

[1] Clarence King, *Geological Exploration of the Fortieth Parallel Survey*, Vol. I, p. 161.



Character	Thickness	Formation		
Fossil bearing horizons				
Red shales—locally sandy—with interbedded coarse gray sandstones. Carries, in lower portion *Aviculipecten Weberensis, A. curticardinalis, A. parvulus, Myalina permiana.* No economic importance.	1,500+ feet	Ankareh Shale	Permian	Carboniferous
Calcareous with sandstones and shales. "Mid-red" shale separates more calcareous upper from more arenaceous lower portion. Carries large fauna, with many new fossil species, chiefly pelecypods including *Pentacrinus* sp., *Myalina permiana, M. aviculoides, Aviculipecten curticardinalis, A. Webercnsis, A. parvulus, A. occidaneus,* Lingulas, Spirifers, Dentalia. Forms country rock for replacement ore bodies and lodes.	1,190 feet	Thaynes Limestone		
Red shale—thinly bedded—fine grained. Bears ripple marks, mud cracks, raindrop imprints. No direct economic importance.	1,180 feet	Woodside Shale		
Calcareous with interbedded quartzite, sandstones and some shale. Carries Lingulidiscina sp., Productus cora, Productus sp., Plagioglypta canua, Euphemus subpapillosus, Bellerophon, sp. Forms country rock, for principal bonanza replacement ore bodies.	500 feet	Park City Limestone	Pennsylvanian	
Gray quartzite, massively bedded, homogeneous, dense. Carries, in Weber Canyon, *Lingula* sp., *Productus subhorridus, Schizodus* sp., *Plagioglypta canua, Euphemus subpapillosus.* Forms wall or walls of lead-silver lodes.	1,350+ feet	Weber Quartzite		

Columnar section of portion of Carboniferous, Big Cottonwood Canyon, Wasatch Range, Utah

Character.—That part of this formation which outcrops in this region is made up of gray quartzite, with comparatively insignificant exceptions of cherty patches and intercalated limestone. This, the upper portion, is characterized by its general massiveness, both in bedding, which is rarely less than 4 and frequently 8 to 15 feet in thickness, and in absence of parting planes. On fresh fracture it is light brownish-gray in color, and it weathers to a glistening polished surface of a lighter whitish shade. The normal quartzite is fine, even-grained, and dense. The exceedingly brittle nature of the rock causes it to chip into sharply angular irregular fragments, or, when ground up in a fracture zone, to appear as a glistening white, sugary portion, inclosing less finely comminuted quartzite. The cleanness of the rock has been demonstrated by repeated chemical analyses, which show a very high percentage of silica. Thus analysis of a specimen of this quartzite from Big Cottonwood Canyon shows 95.80 per cent. of silica.

These lithologic characteristics are maintained with remarkable uniformity throughout the formation. Exceptions noted within this district are so rare as to be insignificant.

Topographically this quartzite stands up as knobs or ledgy massive blocks and as prominent broad spurs falling off by precipitous slopes.

That part of this great formation which is not present in this area, embracing the middle and basal portions, outcrops in prominent cliffs just south of this district. Excepting a few thin limestone beds near its top, the middle portion is massive quartzite, and in the lower part the intercalated limestone members increase in number and thickness. In Big Cottonwood Canyon the massive, dense character of the quartzite is preserved, and a few limestones are intercalated. A thin, crinoidal sandstone occurs about 130 feet from the top; a thin, pitted, cavernous, grayish-white quartzite, 460 feet below that; and a thinly banded, calcareous quartzite, 430 feet farther down. In Weber Canyon this great formation is most characteristically exposed as a massive, dense, homogeneous quartzite. The insignificant exceptions are a curiously pitted and marked horizon of quartzite just below the top and a few thin limestones in the basal portion.

Distribution and thickness.—The main area of this formation

exposed in this district is an oblong tract which extends south from Park City about 3 miles, with an average width of a mile. From Bald Mountain an irregular, much broken arm extends eastward between two great faulted zones, and to the south and southwest about the eastern end of Bonanza Flat are isolated horses in intrusives. This quartzite forms the outcrops on the slopes which inclose Park City on all sides. It is particularly well exposed on the salient bluffs west of the city, and is deeply incised by each of the canyons which lead south up to the mines. Characteristic outcrops have been revealed in Woodside Gulch by cutting the King Road between the Alice and Woodside properties; in Empire Canyon in the vicinity of the adits to the Daly Judge and to the Alliance tunnels, and in upper Ontario Canyon.

The thickness of the portion of this formation which appears in this district cannot be determined precisely, because nowhere within the area was a continuous exposure observed. The Ontario No. 3 shaft and workings cut "Ontario" quartzite, dipping about 20 degrees, to a depth of 1,620 feet, or a thickness of approximately 1,500 feet. The collar of the shaft lies on the side of a canyon which has been cut deep into the formation below its upper contact. This contact is exposed elsewhere to the north and northwest, but the thickness of quartzite which has been removed by denudation down to the stratigraphic horizon in which the collar of the shaft is located is uncertain, except that it is several hundred feet. The thickness of Weber quartzite exposed within the district may thus be regarded as approximately 2,000 feet. The minimum thickness of the underlying portion would be 1,500 feet. The accurate determination must await the working-out of structure and measurement of any possible great faults. Pending that, it may be tentatively considered as 3,500 feet. The thickness of the part exposed on the north side of Big Cottonwood Canyon was 1,340 feet. King and the geologists of the Fortieth Parallel estimated the thickness exposed in Weber Canyon to be 6,000 feet.

Age and stratigraphic relations.—The geologic age of the Weber quartzite was regarded by the early geological workers in this region as "Upper Carboniferous." They did not find fossils in the quartzite itself, but based this conclusion on the stratigraphic relation of this formation to fossiliferous limestones above and below.

During the present investigation paleontologic evidence was obtained from the quartzite itself, from limestone intercalated in its lower portion, and from overlying limestone formations, which definitely proves the age of the Weber quartzite to be "upper Carboniferous". During the season of 1903 Dr. T. W. Stanton discovered fossils in the quartzite in Weber Canyon. They occurred about 2 miles west of Croydon Station, and at 1,800 to 2,000 feet below the top of the Weber quartzite formation.

These fossils prove this quartzite to be of Pennsylvanian (upper Carboniferous) age. No fossils have been found, in the quartzite within or adjacent to the Park City district. Definite faunas were obtained, however, from limestones intercalated in the quartzite on the north side of Snake Creek which underlies the part which outcrops in the Park City area. These collections (101–7), like those from the formation in Weber Canyon, show faunas of Pennsylvanian (upper Carboniferous) age. Further, faunas from overlying limestone formations in both the Park City and Weber Canyon areas are Pennsylvanian. Accordingly the occurrence of Pennsylvanian faunas in the base of this formation and overlying limestone demonstrates that the age of the Weber quartzite is Pennsylvanian. The transition in Weber Canyon from the underlying great Wasatch limestone formation to the Weber quartzite is by gradually increasing siliceous contents through varicolored sandstones, which give way to alternating limestones and quartzites, and finally to quartzite with intercalated limestone. In Snake Creek the passage upward and northward into the Weber quartzite is by a corresponding succession of limestones intercalated in quartzite.

The passage from this great quartzite into the overlying formation had been subjected to considerable study without definite results. Accordingly in the present investigation special attention was given to this question. It had been reported by one geologist that a marked unconformity existed between this quartzite and the overlying limestone. During the present survey no unconformity was found. On the contrary, excellent exposures showed on careful inspection apparently complete conformity. The lithologic character of the sediments also indicated that a full record is here shown of a gradual normal transition. Exposures in Woodside Canyon show a succes-

sion of calcareous sandstones, normal sandstones, and arenaceous quartzites immediately above characteristic massive Ontario quartzite —apparently a normal transition. In Big Cottonwood Canyon, a few miles to the west of this area, the quartzite gives way upward to a sequence of sandy beds. In Weber Canyon the precise contact was not sufficiently exposed to demonstrate conformability, but the limit and extent observed gave no evidence of unconformity. Immediately overlying normal Weber quartzite is a coffee-colored and white sandstone, variably coarse and fine, about 150 feet thick, succeeded by the regular calcareous succession.

These accordant features, lack of reliable evidence of unconformity, and a lithologic succession tending to show conformity between these formations, are further supported by paleontologic evidence. In the Park City District the base of the overlying limestone formation carries a distinctive fauna. Members of this same fauna, as indentified by Dr. Girty, occur in Weber Canyon in the equivalent limestone at a corresponding distance above the quartzite (about 250 to 300 feet), and also about 1,800 to 2,000 feet below in Weber quartzite. This fact in itself seems to show conclusively that no break in the paleontologic succession took place, and thus that there was no break in the sedimentation, or, in other words, that the Weber quartzite and the overlying limestone formation are conformable.

PARK CITY FORMATION

Name.—The Park City formation is named after the district, in recognition of the fact that it is the formation which has yielded the bonanzas that during the last decade have made the district famous.

Character.—This formation is made up in large part of calcareous members, but it also embraces several sandstones and quartzites. In general, it comprises a thick limestone in its lower part, several minor limestones in its upper part, and a number of thin calcareous beds toward the base, with intercalated quartzites and sandstones. Along the King road the lower portion of the formation is seen to be made up of normal gray limestones, cherty limestones, brown calcareous and shaly sandstone, red, brown, and olive shales. The lower half of the formation is there seen to include two important limestone members and three minor quartzites. Overlying these,

and forming the top of Treasure Hill, are various types of siliceous beds, sandstones, quartzites, etc.

The exposure in the type section a few miles to the west in Big Cottonwood Canyon presents the best section observed.

TYPE SECTION, BIG COTTONWOOD CANYON

Description

Thickness in Feet	
19	Grayish-white limestone, with fine gray and white cherts increasing toward bottom.
19	Shale and fine buff sandstone.
7	Dark-gray limestone, thin chert, red shale, and porous loose member at base.
11	Sandy shale.
21	Yellowish-gray quartzitic sandstone, changing into cherty white limestone below.
52	Gray and white banded chert, with few white sandstone intercalations.
8	Fine calcareous sandstone, with lentils of chert and brecciated fragments of sandstone.
104	Float of buff sandstone and shale, becoming more shaly and calcareous at base.
18	Siliceous arkose, comprising mainly rounded quartz grains and feldspars cemented with ferruginous material.
20	Compact grayish quartzite.
8	White, compact, sugary sandstone, fossiliferous at base.
30	Fine gray and pink, massive quartzite, with brown sandstone and gray-white chert bands near base.
27	Light-gray limestone, weathering whitish gray with an imbricated pattern; fine gray limestone near base; carries good faunas at two horizons in particular, 20 and 55 feet above the base respectively.
24	Gray calcareous sandstone.
9	Fine gray limestone.
36	Float showing bits of grayish and brown calcareous sandstone.
22	Sandy limestone, more calcareous at base, with cavernous weathered surface.
31	Float, upper sandy beds at top of Weber quartzite.

Distribution.—The Park City formation extends around the center of the district in the general form of a U (with base pointing north). Its irregular and interrupted outcrop stretches from Bonanza Flat northward across the prominent eastern spur, passing the Daly West, Daly, and Silver King mines, thence northerly to a point opposite

Park City, where it swings northeast and eastward around to the north of the city, whence, continuing the curve, it reappears with a southerly strike near the base of the eastern slopes of the range. The continuity of this general course has been much interrupted by intrusives, extrusives, and faulting. The most characteristic, and also the most extensive, exposures are those lying west and east of Park City, forming respectively Treasure Hill and Twin Knobs.

This formation characteristically forms domar knobs and spurs of moderately steep slope intermediate in degree between the resistant quartzite below and the non-resistant shale above. No good natural exposures of the entire formation are known in this area. The absence of cliff-making members, the presence of weaker members, and the thick growth of aspen and brush which characterize this formation, all contribute to cover its surface, to render it inaccessible, and to prevent careful examination and measurement of its members.

Thickness.—The exposures in this area do not afford a basis for a close estimate of the thickness of the Park City formation. Crosscuts in the Silver King and Daly West mines should, under normal conditions, yield the desired data, but strike-faulting in both properties has so complexly duplicated the succession as to render measurement of its thickness little more than approximation. The total thickness indicated by the Treasure Hill body is approximately 700 feet. The best and the only reliable section observed is the type section in Big Cottonwood Canyon, described above. The thickness of this formation at that locality measured 590 feet.

Age and stratigraphic relations.—The age of the Park City formation is proved, by several faunas collected from calcareous members in the district in Big Cottonwood Canyon and in Weber Canyon, to be Pennsylvanian (upper Carboniferous). Two of the type fossils are particularly indicative: the Bellerophon, as seen in the lower portion of the formation along the King road, in Woodside Gulch, and the Orbiculoidea, of common occurrence in the gray shaly limestones, the lower part of the formation throughout the district. The identification of these faunas in the Cottonwood and Weber Canyon regions makes possible the correlation of this formation with its equivalents to the west and north. The association of *Bellerophon* sp., *Productus cora*, and *Orbiculoidea* sp., and the stratigraphic position of these faunas

leads Dr. Girty to suggest the correlation of this formation with the Bellerophon limestone in the Uintas. With regard to the position of the ore-bearing limestones of this formation in comparison with that of others in the Utah mining camps, they appear to be somewhat higher than the Highland Boy, Commercial, and Jordan limestones at Bingham (upper portion of the Weber quartzite); higher than the Great Blue limestone at Mercur (the Wasatch, Mississippian, or lower Carboniferous); higher than the Eureka and Godiva limestones at Tintic (Mississippian); and higher than the great limestone of Emma Hill at Alta in middle Cottonwood Canyon (Mississippian or lower Carboniferous). Thus the Park City formation is much younger than any of the limestones in Utah which have been found to bear ore bodies, except those at Bingham, and it is believed to be next younger than the Bingham formation.

No unconformity was observed with either the underlying Ontario quartzite or the overlying shale, or between members within the formation. Accordingly it would seem that sedimentation proceeded unbroken from Mississippian time on through that period of the Pennsylvanian represented by the Park City formation.

WOODSIDE SHALE

Name.—The Woodside shale is named after Woodside Gulch, as the best exposed section of these sediments in the district is at the head of this gulch, on the slope which overlooks the Silver King plant from the west.

Character.—This great formation is a lithologic unit, being composed from bottom to top, without significant exception, of fine-grained, dark-red shale. A shaly parting sometimes gives way to very thin laminations, but the general homogeneous lithologic character is maintained with wonderful uniformity. In rare exceptions a slight increase in coarseness of texture produces a fine grained sandstone, or variations in color result in buff, brown, and greenish-gray shales; but such variations are extremely limited in number and extent.

The characteristic topography which has developed on such a lithologically homogeneous formation is a full, even, uninterrupted slope. This is commonly densely overgrown with rank grasses, shrubs and aspen.

The formation has no direct economic importance, as it affords neither ore bodies nor building stone, nor other economic products. Indirectly, however, its tendency to take off surface drainage and its enormous capacity for water render it an important factor in mining, especially in sinking deep shafts or in running long tunnels.

Distribution and thickness.—The Woodside shale appears in this district in three principal areas. In a highly metamorphosed condition as spotted dark-red and green argillite it occurs on the north face of Jupiter Peak and northward along the east side of Pioneer Ridge, and also as an argillite in the gap next west of Lucky Bill gap and on the north side of the Quincy spur. In its normal development it appears northwest of the Daly West shaft from the Morgan shaft to the Diamond-Nimrod shaft and along the west side of Empire Canyon, and especially characteristic in the slope above and to the west of the Silver King mine. To the east of Park City it reappears striking southerly on the eastern slope of the range.

The thickness of this shale varies considerably. In the type section of Big Cottonwood, which was studied and measured with unusual care, this formation was found to be 1,180 feet thick. In the Park City district the best opportunity for its determination was afforded by the sinking of the deep shaft by the Silver King Consolidated Company, although even this is not entirely free from possibly inaccurate estimate owing to faulting. This shaft is located on the northeast side of Crescent Ridge just over the divide northwestward from the Silver King property. It passed through this red-shale formation for a distance of 800 feet, which, reckoning the average dip as 30°, affords a thickness of 700 feet.

Age and stratigraphic relations.—No fossils were observed in this shale, neither was any stratigraphic evidence found which would directly connect this formation in age with either of the inclosing fossiliferous formations. Lithologically, however, this shale finds its equivalent in one important member and several thin ones in the next overlying formation and in the great thickness of red shale of the Ankareh formation. These lithologic resemblances show that the conditions under which this formation was deposited were those which prevailed during the deposition of the succeeding rather than that of the preceding formation. Accordingly the Woodside shale

will be grouped with the overlying fossiliferous limestone as of Permian age.

THAYNES FORMATION

Name.—This formation is named Thaynes after a canyon whose deep and extended incision affords the best exposures of this formation within the district.

Character.—This is essentially a calcareous formation. It comprises two parts separated by a red-shale member, each made up of limestone, calcareous sandstone, normal sandstone, and shale. Most of the true limestones are in the upper part, and the sandstones predominate in the lower part, though each type is found throughout. A very characteristic lithologic type occurring at many horizons in the formation is a dense, homogeneous, blue-gray, calcareous sandstone, which appears superficially to be a limestone, but on exposure to the weather loses its low calcareous content and becomes a medium fine-grained, brown sandstone. These are among the richest fossiliferous members of the formations, as is shown below. These members, the abundant and characteristic faunas, and the red-shale member—the "mid-red" shale—serve to mark this formation and to enable one readily to distinguished it from the Park City formation. Topographically, the outcrop forms abrupt cliffs, and the dip slopes and basset edges, broad flat slopes. Its surface is brushy and ledgy. A number of partial sections were measured and studied with great care for purposes of correlation, identification, and structural proofs. No complete sections or exposures which were not complexly faulted, intruded, or metamorphosed, which would serve for a standard section, were found within the district. The nearest point where suitable exposures could be found was about 3 miles west, in the north side of Big Cottonwood Canyon, where in several parallel spurs this formation occurs in excellent unbroken exposures. The composition of the formation in that section, including lithology, thickness, and fossil characteristics, is briefly stated below:

SECTION OF THAYNES FORMATION (PERMIAN) IN BIG COTTONWOOD CANYON

Thickness in Feet	*Lithology*
1	Sandstone, massive, even, fine-grained, basal member, Argenta formation.
1	Limestone, blue, locally sandy, fossiliferous.

Thickness in feet	
12	Shale, fine, gray-green.
½	Limestone, blue-gray, cavernous, fossiliferous.
2½	Limestone transition from shale through sandstone, fossiliferous.
14	Sandstone, gray-brown, with calcareous shale intercalations, fossiliferous.
5	Shale, maroon, fine-banded.
½	Limestone, gray, impure, semicrystalline, fossiliferous.
24	Limestone, light gray-blue, massive, sandy, fossiliferous.
16	Shale, gray-brown.
5	Limestone, impure, gray, massive, fossiliferous.
4	Shale, gray to buff.
14	Sandstone, massive, gray-brown, vertical sheeting, fossiliferous.
42	Shale and sandstone, green to brown, calcareous intercalations.
4	Sandstone, gray, finely laminated, chert lenses.
8	Shales.
20	Limestone, fine, blue, with intercalated ripple-marked sandstones, lenticular gray cherts, and biotitic bed, bearing fossils.
15	Shale, olive.
4	Sandstone, olive-gray, massive, weathers rusty, trails, fucoids, and imprints.
5	Limestone, bluish, matrix inclosing "tangle" stringers of ferruginous sandstone.
4	Limestone, impure, blue, very fossiliferous.
19	Shale, olive, fine-grained.
7	Limestone, sandy and shaly.
8	Limestone, blue to gray, spheroidal weathering, fossiliferous.
14	Débris, lime with intercalated shale.
14	Limestone, dark blue, locally shaly, weathers rough, several highly fossiliferous horizons.
10	Shale, brown, inclosing sandy bed.
5¾	Limestone, gray-blue, gray chert lenses, fossiliferous.
4	Shale, brown with green tinge.
6	Limestone, coarse shells, gray chert band.
14	Limestone, dark blue, sandy, massive.
35	Limestone, deep blue, weathers rusty, fossiliferous.
11	Sandstone, calcareous, rusty, breaks in slabs.
10	Limestone.
66	Sandstone, gray-black, shaly, bands black slaty shale, fossiliferous.
168	Sandstone, calcareous, finely laminated, highly fossiliferous.
20	Shale, maroon.
30	Float, varicolored shale.
64	Shale, green, buff, olive, maroon, yellow.
34	Sandstone, gray, calcareous, intercalated shales.
5	Limestone, gray, intercalated, calcareous, gray sandstone.
14	Sandstone, greenish-brown, intercalated shales.

Thickness in feet	
4	Limestone, gray-blue, fossiliferous.
17	Shale, olive, with three fossiliferous argillaceous limestones.
5	Limestone.
370	Limestone, blue; shale, olive-brown; sandstone, calcareous; alternating series, varying much in color and texture, fossiliferous.

Talus, containing shale regarded as top of Woodside formation.

Distribution and thickness.—The Thaynes formation is one of the two most extensively exposed formations in this district. On the western flank of the Park City anticline it forms both of the inclosing walls of Thaynes Canyon from head to mouth, all the middle and headward portions of White Pine Canyon, and thence strikes southwest into Big Cottonwood Canyon. It is again seen in the main fault zone of the district overlying the great mines. Thus it forms the prominent ledges west of the upper portion of Empire Canyon, just opposite the Daly Mine, the spur extending from the Daly West mine to Morgan Knob, and the cliffs which overlook the Daly Judge amphitheater. On the eastern flank of the anticline the cropping of this formation is exposed about the heads of Heber, McCune, and Pocatello gulches, and at the extreme southeast crops in a triangular area just north of Cottonwood Canyon.

The best measure of the thickness of this formation was obtained in Big Cottonwood Canyon, where, as shown above, the upper part amounts to 630 feet, the "mid-red" shale to 115 feet, and the lower part to 445 feet, the whole formation thus aggregating 1,190 feet. Within the Park City area proper no exposure was found suitable for measurement, so complex and universal was the deformation in this region. The difference in thickness of exposures of this formation on the eastern and western sides of the district may be apparent rather than actual, as on the Heber road near the top of the eastern exposure red-shale crops which is probably the "mid-red" shale, and the same is true in the Cottonwood exposure. It would thus appear that the eastern exposures embrace a portion of the formation only—that is, the part lying below the "mid-red" shale, the upper portion being either truncated by intrusives or buried by extrusives.

Age and stratigraphic relations.—Excellent fossil evidence indicates that the geologic age of the Thaynes formation is probably Permian.

Dr. Girty, who has examined the faunas collected from it and prepared the list of species given below, states that

"the fauna and horizon are those which in the Fortieth Parallel Survey Reports are called Permo-Carboniferous in the Wasatch and Uinta Mountains. The fauna consists almost exclusively of pelecypods, chiefly pectinoids, a few of which are described in the reports above referred to. With these exceptions the fauna was entirely new to me. . . . . It now seems probable that the fauna will be correlated with the Permian of the Grand Canyon section, and will prove to be in fact Paleozoic."[1]

The limestones and the peculiar calcareous sandstones are rich in organic remains. In their characteristic and distinctive fauna three forms are almost universally present, *Myalina*, *aviculipecten*, and *lingula*, while Spirifers and Dentalia are usually present in faunas from limestones. The first three forms are found throughout the Thaynes formation, including the highest and lowest members, and are indicative of this formation. *Pentacrinus*, which also serves as a valuable index, is limited to the part lying above the "mid-red" shale. The following species in the list submitted have been identified by Dr. Girty:

PARTIAL LIST OF PERMIAN FOSSILS IDENTIFIED IN PARK CITY DISTRICT

Pentacrinus sp.	*Aviculipecten curticardinalis*
Myalina permiana	*Aviculipecten Weberensis*
Myalina aviculoides	*Aviculipecten parvulus*
Aviculipecten occidaneus	

In addition to these recognized forms, Dr. Girty states that the collections from this formation in the Park City District include fully thirty new species, and that nearly as many more have been found outside the district.

In its stratigraphic relations this formation is intimately related to the two inclosing shale formations, in that during its deposition the same conditions frequently prevailed as during their deposition. No great unconformity either above or below was noted, though a slight unconformity by erosion was observed at one horizon within this formation, and others doubtless exist.

The persistence of certain members of the Thaynes formation is noteworthy. Thus the "mid-red" shale, with a thickness of only

[1] Extract from report on collections submitted by the writer for identification by Dr. Girty, Paleontologist, U. S. Geological Survey, dated August 11, 1903.

115 feet in the Park City area, is found 3 miles to the west in the Big Cottonwood region and 40 miles to the north in Weber Canyon. Still more noteworthy is the occurrence of thin limestones at equivalent stratigraphic positions in the formation and bearing identical faunas in this district, and again in the Big Cottonwood section 2 to 3 miles to the west. Not sufficient work in following special members was done to warrant the affirmation that this persistence or equivalency is actual stratigraphic continuity, though in the case of the thicker formations this is doubtless true, and it is probably true of some of the thinner limestones. This striking continuity probably indicates that the conditions under which these members were formed were brought about over extensive areas by wide-spread land movements of equal intensity throughout the region.

ANKAREH FORMATION

Name.—The name for this formation is taken from the ridge on which it attains its fullest and most characteristic development within the district. The ridge has been named by the writer for the purpose of rendering descriptions shorter and more definite. One of the most striking characteristics of this ridge is the red color imparted by the shales, and as *ankareh* is the word for "red" in the dialect of the Uinta Utes, the local Indian tribe, the adoption of the word *Ankareh* as the name of this ridge seems most fitting. The extension of the use of this term from the ridge to the formation is no less appropriate, as this formation constitutes the base of the main red shale and sandstone formation in the Wasatch, whose striking red color is most characteristically displayed on prominent spurs immediately west of Park City.

Character.—As a whole, this formation is composed of siliceous detrital deposits. They are chiefly red shales, which frequently become sandy through considerable thicknesses. It also includes a number of well-marked beds of rather coarse, whitish-gray sandstone, which range from 20 to 55 feet in thickness. A few fossiliferous, grayish-blue limestones are also intercalated, but these are exceptional and only a few feet thick. The division between this and the underlying formation is made on lithologic grounds, calcareous members characterizing the Thaynes formation and siliceous the Ankareh

formation. For the basal member the coarse, massive sandstone is taken which lies at the base of the red shale as a whole, and immediately overlies a thin limestone. Only a portion of this formation occurs within this district, the highest part being marked by a prominent massive, white sandstone member.

The non-resistant character of the beds of this formation as a whole results in the topographic development along its outcrop of even full slopes, which are broken only by benches on the sandy members. These slopes are usually thickly covered with aspen, rank grasses and brush. They are dry, rarely forming water sources. No economic values, either in ore or in stone, have yet been found to occur in its members.

Distribution and thickness.—The formation outcrops in only two areas within the district. The principal one is an N-shaped zone in the extreme northwestern corner of the area; thence it strikes westerly, and is plainly visible in characteristic topographic and lithologic development on each of the succeeding ridges to the west of Park City which head at Big Cottonwood Canyon. The second area, which has never been recognized as such hitherto, is on Pioneer Ridge, between Crescent Ridge and Jupiter Hill, where red shale of this formation forms the spur between the Kearns-Keith or Sampson amphitheater and the Jupiter amphitheater immediately south.

The best exposure for the measurement of the thickness of that portion of the formation which crops in this district is at the west side of Thaynes, toward its mouth. This was carefully studied and measured, but, owing to frequent interruption by vegetation and débris, it is incomplete, and, owing to the probability of deformation by faulting, any estimate of the thickness would be of little value. In the Big Cottonwood standard section the thickness of the portion which crops in the Park City District was found to be 1,300 feet.

Age and stratigraphic relations.—The age of the Ankareh formation, so far as indicated by meagre paleontological evidence, is Permian. The fossil evidence on which this determination is based comprises three lots from the standard Big Cottonwood Section and scattering collections from within the Park City District. The lowest two lots, one from coarse sandstone, the other from a thin limestone, both within 200 feet of the Thaynes formation, belong with the fauna

of the underlying limestone, and like it are Permian. This definitely fixes the lower portion of the Ankareh formation as Permian, but the division between this known portion and the overlying shales and sandstones which have been considered Triassic, remains undetermined. In the standard section just below the main sandstone member, and in the Thaynes section in this sandstone succession, petrified wood and bark were found; but these hardly marked the age of the inclosing beds. For the purpose of this report the portion of this formation which lies within this district may be considered as Permian. The delimitation of the upper part may best be left to future workers in adjacent areas where the entire section is exposed.

Stratigraphically the lower part of this formation is shown by the character of the included faunas to belong with the Permian. Doubtless deposition took place without interruption between these formations. The transition upward into sandstones, which are well bedded and also coarsely crossbedded, points to probable depression from shore conditions to slightly deeper water and strong currents.

TRIASSIC

Within this district no sediments have been found which carry Triassic fossils. To the north and northwest, however, the Park City formations pass upward through several hundred feet of red shale into brown, red, pink, and white sandstones. These are frequently massive and heavily bedded, in striking occurrences are coarsely crossbedded, and toward the top are quartzitic. Disregarding possible faulting, they aggregate about 1,550 feet in thickness. The age of these sandstones has always been regarded as Triassic, as they overlie Permian and underlie Jurassic.

JURASSIC

Overlying these sandstones is a succession of fine-grained gray limestones several hundred feet in thickness, which yielded sufficient organic remains to prove them of Jurassic age. These roughly measured 400 feet in thickness, and were overlain by concealed, partly calcareous beds about 500 feet in thickness.

The following forms in these collections have been identified by Dr. T. W. Stanton:

Camptonectes pertenuistriatus Hall & Whitfield.
Cucullaea haguei Meek?
Astarte sp.
Pleuromya subcompressa Meek.
Cerithium? sp.
Nerinea sp.
Gryphaea calceola var. *nebrascensis* M. & H.
Pinna kingi Meek.
Cyprina? sp.
Pentacrinus sp
Ostrea sp.
Lima (*Plagiostoma*) *occidentalis* Hall & Whitfield.
Gervillia sp.

GENERAL STRUCTURE

In the course of mapping the above-described geologic formations in this district, and of reconnaissance work in adjoining areas, several structural features were discovered which bear significantly upon the location and deformation of the ore-bearing formations. Some time must necessarily elapse before the complete report giving these results can appear. Accordingly, in response to several urgent requests from operators for information, this opportunity is taken to present without further delay a general statement of some of the more important structural features.

The general anticlinal structure of the Paleozoic and Mesozoic beds which characterize the Wasatch as a whole is interrupted in this central portion by a transverse (east-west) anticline or dome. Sediments ranging from Cambrian to Tertiary here dip northerly and southerly quaquaversally from a series of laccolithic masses. These include, from west to east, the porphyritic granite of Lone Peak and Little Cottonwood Canyon, the granodiorite at the head of Little Cottonwood Canyon in the vicinity of Alta, the coarse and fine-grained dioritic masses at the heads of Big and Little Cottonwood Canyons, and the northeast extensions in the form of dikes. These several masses constitute a mammoth composite laccolith. It is noteworthy that these intrusions have taken place along a zone coinciding in location and course with the extension of the Uinta axis across the Wasatch. This fact, together with the influence of these masses in doming the structure athwart the general course of the Wasatch, naturally raises a query as to a similar influence in the formation of the Uintas. This transverse Wasatch dome and the Uinta dome are separated topographically, though not structurally, by a north-south

trough. Into this, and thus blanketing the surface connection of these structures, extensive and thick masses of andesite have flowed.

That portion of this region known as the Park City District is traversed diagonally by this axis. The sediments in this area have been cut, deformed, and altered by a series of intrusives, and andesite flows cover the sediments at the northeast. These sediments rim around the intrusives and dip off from their flanks. The area thus embraces the northeast end of the great composite laccolith of the middle Wasatch.

The broad structure of the formations within the Park City District proper is that of an anticline pitching northerly. The general strike follows the course of a U, the base of the letter being at the north. At the center, along the main axis which passes north-northeast just east of Park City, occurs an extensive area of Weber quartzite, from which the overlying younger formations dip—in general to the west side on the west and to the east on the east. Immediately north of Park City these strikes converge and unite to form the nose of the pitching fold.

This structure, however, is true only in a general sense, as it is greatly modified by minor folding and extensive faulting. Athwart this anticline, in a general east-west course, extends a series of intrusive masses. These include the diorite stock of Clayton Peak at the extreme southwest, east of this the stocks and dikes of andesite porphyry which extend eastward diagonally across this area and upward through all sedimentary formations from the Weber to the Thaynes, and next beyond to the east extensive thick flows of andesite. These are the highest members of the chain of intrusives which lie athwart the course of the range at this point. They occupy the normal position of sediments, and thus interrupt the general anticlinal structure above described to only a minor degree by local folding.

Three great systems of fracturing and faulting further break the broad structure, trending north-south, northeast-southwest, and northwest-southeast (east-west), respectively.

One of these fracture systems cuts across the nose of the anticline on its northeast side as a north-south line of dislocation, which is marked by the eastern inclosing wall of Deer Valley Meadow and Frog Valley. Along this fault the displacement has been such that

the eastern side lies farther south than the western. In the same deformational sense the western member, especially that area of Weber quartzite lying east of Park City and that forming Bald Eagle Mountain, has moved eastward up this same fault plane, overriding geologically higher formations. As a result of this extensive overthrust faulting, two formations, aggregating 2,000 feet in thickness, have been overridden until the Weber outcrops against the Thaynes formation. The economic importance of this discovery lies in the fact that the principal ore-bearing limestone of the district which had been believed hitherto to strike north from Park City and to disappear beneath the extrusives, in reality occurs immediately east of the settlement in an easily accessible locality.

The principal zone of fissuring in this region trends across the central portion of the district in a northeast-southwest direction and dips steeply toward the northwest. It embraces the lodes which have afforded the valuable output from the Ontario, Daly, Daly West, and Daly Judge properties. The faulting on the main fissure of the system in its eastern extent, the Ontario, as measured in the vicinity of Ontario shaft No. 3, was relatively a downward movement of the north or hanging wall side, aggregating 330 feet. Correspondingly great dislocation occurred on the most important member of this system in its western part, the Daly-Daly West fissure, also on other members; and in certain instances a relative downward movement of the *south* or hanging wall side of south-dipping fissures is clearly shown.

North of this zone members of the northwest-southeast system appear in a series known after its principal member, the Massachusetts fault. This may be best seen trending west-northwest and standing about vertical in the Daly Judge tunnel and at the Massachusetts shaft. Its structural importance lies in the fact that the north side has been moved along it relatively westward about 2,500 feet. Its economic importance arises from the fact that its recognition and solution answers the hitherto standing query as to the relation of the ore-bearing limestones of the Silver King and Daly West properties, respectively; namely, they are portions of the same formation—the Park City limestone.

A similar result of these east-west faults is shown on the west side

of Empire Canyon, opposite Daly shaft No. 2. The limestone cliffs forming that wall of the canyon terminate abruptly on the north, and the same beds (Thaynes limestone) reappear 5,000 feet to the west in Crescent Ridge, on the north side of a strongly defined east-west fault.

A significant fault structure has also been brought out in the course of this work to the east of the Ontario fracture zone, on the extreme eastern slope of the range. A block (or wedge) averaging 2 miles in width north and south, and made up of the regular sedimentary succession, including the Weber to Thaynes formations and intruded andesite porphyries, has moved bodily to the east at least 2 miles. Its northern limit is a strong east-west fault, followed by McHenry Canyon. Its southern wall is a companion fault which crosses Cottonwood Canyon near its mouth about a mile southeast of the Valeo Mine. The economic significance of this discovery is that the desirable ore-bearing limestones should not be sought in their normal strike and position, and that within the extent of this block they lie at least 2 miles beyond to the east at an unknown depth beneath thick andesite extrusives. The scientific bearing of this structure, however, is of deeper interest, in view of the present eager search for evidence on the manner of intrusion, especially as to the disposition of the rock which previous to intrusion occupied the space subsequently taken by the igneous mass. The general aspects of this occurrence are most suggestive.

From the foregoing statements regarding intrusives and structure, it is to be noted that a series of intrusives lie in a narrow east-west belt extending across the range; that these appear on other distinct evidence to have invaded this area from the west, breaking upward and eastward; that the intrusives in this area are thus the highest and easternmost members; that in the path and ahead of this chain of intruded igneous masses occurred the maximum deformation and dislocation; that slightly to one side on the north sediments were broken and driven eastward over geologically higher members; and that directly ahead of the invading wedge of intrusives the country gave way and moved eastward at least 2 miles.

RESTORATIONS OF CERTAIN DEVONIAN CEPHALOPODS WITH DESCRIPTIONS OF NEW SPECIES[1]

A cephalopod fauna remarkable for the form of some of its species as well as for the abundance of individuals occurs in the hydraulic limestone of Middle Devonian age near Milwaukee, Wis. The specimens are crushed to such an extent by pressure applied at various angles with reference to the vertical axis, that a hasty study would probably result in their separation into a large number of species and perhaps genera. In fact, early collectors were led to believe that at least twenty species were represented, whereas, all should probably be included in nine or ten species.

In order that these distorted forms might be clearly understood, and to reduce as much as possible the liability to error in their determination, restorations in clay and later in plaster were made from careful measurements of actual specimens. In these restorations it was found necessary to restore the apex without reference to the fossils, since in no specimen was that portion of the shell preserved in its entirety. For example, in *Gomphoceras calvini* the lower one and one-quarter inches of the restoration is hypothetical, although in *G. wisconsinense* practically the whole specimen is known. The transverse section was made circular in the restorations of all the species. In the case of *G. wisconsinense* this was doubtless the true shape, but it is possible that in two of the restorations (*G. whitfieldi* and *G. fusiforme*) the cross-section was elliptical.

The rim of the aperture of *G. wisconsinense*, *G. calvini*, and *G. fusiforme* is pretty well known, but in *G. whitfieldi* its exact contour is in doubt. It is difficult in all cases to determine the position, if any, of the hyponomic sinus.

It should be remembered that the restorations in this paper are in every case of the interior. If a restoration were made of the exterior, account must necessarily be taken of the thickening of that portion of the shell forming the chamber of habitation. In none of our

[1] Published by permission of the Director of the Wisconsin Natural History Survey. The writer is indebted to Dr. R. Ruedemann for suggestions and criticisms.

specimens is this thickening indicated, but it has been shown by Dr. R. Ruedemann[1] that in certain Ordovician cephalopods "the slight constriction of the living chamber [shown in the cast of the interior] is largely due to a thickening of the shell in apertural direction, evidently a gerontic feature." It is possible that the exteriors of the

FIG. 1.—Lateral view of an exceptionally well-preserved specimen of *Gomphoceras wisconsinense* N. S. The measurements from which the model (Fig. 2) was constructed were largely from this specimen. The original is from Milwaukee and is now in the Public Museum, Milwaukee.

upper portion of the shells of *G. wisconsinense* and *G. calvini* were much less concave than the interior, or were even convex.

A comparison of these restorations with the fossils shows that a number of the specimens which appeared at first to be distinct species

[1] *Cephalopods of the Champlain Basin* (1906), p. 503, Fig. 57.

are only peculiarly distorted individuals of well-marked species. The species most distorted is *G. wisconsinense*, a unique and beautiful fossil. In this species it appears that the shell was comparatively thin. The peculiar shape of the shell probably caused a whirling motion as the dead animal sank through the waters to the soft bottom of calcareous mud, where it rested in the position it had in the water immediately before striking the bottom. As a result of this whirling motion, it was seldom that two individuals struck the bottom at precisely the same angle. The effect, whether due to impact or to the weight of the superimposed sediments, was a distortion in different planes resulting in a great variety of fossil forms. In the case of the other species discussed in this paper it appears either that the shells were stronger, or that they reached the bottom with their vertical axis in approximately a horizontal position. Because of one or both of these conditions, the outlines, except in the transverse section, is little changed. The outline of the shells, as has been said, is quite well known, but the internal structure is poorly preserved. The air-chambers are usually preserved, but the position of the siphuncle is, in some species, in doubt, and in only one species is the relation between the siphuncle and hyponomic sinus shown.

FIG. 2.—A restoration in plaster of *Gomphoceras wisconsinense* N. S. The shape of the apex is somewhat in doubt.

The impossibility of determining the position of the siphuncle compels the use of the broader classification used in the older literature.

Gomphoceras wisconsinense n. sp.

(Figs. 1, 2, 3)

Description.—Shell very large, straight, extremely gibbous. Longitudinal section like a pointed amphora. Between the last septum and the apex the

shell rapidly enlarges, becoming ventricose, and then more gradually narrows to near the aperture, where it flanges out.

Chamber of habitation large, about one-third the total length of the shell, gradually enlarging to the last septum. In all specimens the chamber is concave near the aperture, but not in the same degree. No other specimen shows this

FIG. 3.—Exterior view of a crushed specimen of *Gomphoceras wisconsinense* N. S., with a parasitic growth of coral. The dark band near the top of the specimen is a band of pyrite or marcasite which is present on practically all of the specimens a short distance above the last septum, the significance of which is not understood. The original is from Milwaukee and is now in the Public Museum, Milwaukee.

character as strongly developed as the one figured (Fig. 1). Diameter of an uncrushed specimen about 10.5^{cm}. Apertural margin straight.

Air-chambers more than 20, increasing in frequency toward the apex and

varying in width from 16^{mm} near the chamber of habitation to less than 5^{mm} near he apex.

Surface and siphuncle unknown.

One individual of medium size which is crushed laterally measures about 22^{cm} in length and 15^{cm} in its greatest diameter, the actual diameter of the circle being about 10.5^{cm}.

This species most resembles *Gomphoceras mitra* Hall from the Upper Helderberg Limestone of Lexington, Ind.,[1] but differs from it in essen-

FIG. 4.—Exterior view of the concave portion of a well-preserved specimen of *Gomphoceras calvini.*

FIG. 5.—View of *Gomphoceras calvini* N. S., showing the unsymmetrical shape of the upper portion due to the leaning to one side of the chamber of habitation.

tial points. A more careful study of certain species of Gomphoceras from New York, Indiana, and Ohio will show a close relation to *G. wisconsinense.*

Specimens of this cephalopod occur rarely in the Milwaukee Cement Quarry. They are called "horses' hoofs" by the quarrymen because of a fancied resemblance to a hoof. The many shapes

[1] *Paleontology of New York*, Vol. V, Part 2, p. 330, and Plate 119, Supplement Vol. V, Part 2.

in which they occur—due to crushing—have given rise to the belief that a number of species are represented. This, however, does not seem to be the case, as a comparison with the restoration will show (Fig. 3). The shell appears to have been quite thin and easily distorted, in some cases one side being apparently pushed in until it became concave and in contact with the opposite side.

FIG. 6.—Transverse section showing the marginal position of the siphuncle in a crushed specimen of *Gomphoceras calvini* N. S.

Named for the state of Wisconsin.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis.

Gomphoceras whitfieldi, n. sp.

(Figs. 9, 10)

Description.—Shell medium, sub-triangular in a longitudinal section. Transverse section oval or circular. Conch rapidly and regularly enlarging to the point of greatest transverse section, which is about midway between the last septum and the aperture of the chamber of habitation, thence contracting more gradually to the aperture. Apical angle about 45°.

Chamber of habitation wide, but very short; length in one specimen about 3.5^{cm} and greatest diameter about 6.25^{cm}. Aperture large, oval or circular in the border of which there appears to be a sinus.

Air-chambers regular, varying little in depth from the chamber of habitation to near the apex.

Surface and siphuncle unknown.

Length of two individuals about 13^{cm}; greatest diameter of a crushed specimen about 9^{cm}.

FIG. 7.—Restoration in plaster of *Gomphoceras calvini* N. S. The shape of the apex and a portion of the apertural opening are somewhat in doubt.

This species differs from *G. calvini* in its more acute apical angle, its symmetrical form, and its shorter chamber of habitation; from *G. breviposticum* and *G. fusiforme* in its greater size, relatively shorter chamber of habitation, and more obtuse apical angle.

In the restoration the only points in

doubt are the aperture and the transverse section, which may have been somewhat elliptical or subcircular.

Named in honor of Professor R. P. Whitfield, who, besides other well-known writings, has written several papers on the Wisconsin Devonian.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis.

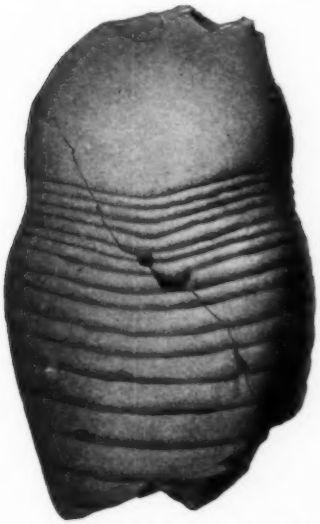


FIG. 8.—A specimen of a gomphoceras which appears to be a new species, but in which the characters are not sufficiently well preserved for specific identification.

FIG. 9.—Restoration of *Gomphoceras whitfieldi* N. S. In this restoration the cross-section is circular. It is, however, possible that the cross-section of the species was oval.

Gomphoceras calvini, n. sp.

(Figs. 4, 5, 6, 7)

Description.—Shell large, fusiform. Transverse section oval or circular. Tube regularly enlarging from near the apex to the greatest transverse diameter which is posterior to the chamber of habitation, at the third or fourth septum; thence contracting to the aperture, but hanging to one side in old age.

Chamber of habitation large. Air-chambers irregular, varying in depth within 9^{cm} of the chamber of habitation, from 5 to 10^{mm}. Hyponomic sinus shallow and apparently on the concave side.

Siphuncle in a crushed specimen 7^{mm} from the periphery on the concave side. Surface unknown. Internal mold frequently covered with parasitic bryozoa and worm (?) tracks.

In none of the specimens which are referred to this species is the apex retained. This species resembles *G. fischeri* of the New York Marcellus, but differs from it in the arrangement of septa. It also resembles *G. plena* Hall.[1]

The restoration of this species was difficult because of the poor

FIG. 10.—View of a crushed specimen of *Gomphoceras whitfieldi* N. S., in which the entire length of the chamber of habitation is preserved.

FIG. 11.—A crushed specimen of *Gomphoceras fusiforme whitfieldi*, showing the position of the sutures and the length of the chamber of habitation.

preservation of the fossils. The apical angle and the rim of the aperture are somewhat in doubt, but are probably correctly shown. It is possible that the transverse section was broadly elliptical. Because of the unsymmetrical form the specimens are usually crushed in the same plane.

Named in honor of Professor Samuel Calvin, State Geologist of Iowa.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis. They occur commonly in the "hard layer."

[1] *Paleontology of New York*, 1888. Supplement to Vol. V, Part 2, Plate 121 A.

Gomphoceras breviposticum Whitfield

(Fig. 13)

Gomphoceras breviposticum Whitfield: *Geology of Wisconsin*, Vol. IV (1873–79), p. 339, Plate XXVI, Fig. 15.

Description.—"Shell rather below medium size, very rapidly expanding from below upward, the rate of increase more rapid toward the base of the outer chamber than in the earliest stages of growth, and again decreasing in the same rate to near the middle of the chamber, and gently contracted above to the aperture. The rate of increase in the type specimen in a length of two inches below the point of greatest diameter, is from a little less than five-eighths of an inch to one inch and seven-eighths; septa moderate, those preserved being about one-eighth of an inch apart, siphuncle lateral in the specimen; aperture sharply sinuate on one side, at a distance of one-fourth of the circle from the position of the siphuncle. No evidence of the lobed contraction of the aperture, as in the Silurian examples of the genus, exists." The siphuncle is on the dorsal side.

FIG. 12.—Restoration in plaster of *Gomphoceras fusiforme whitfield.*

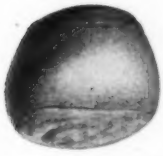


FIG. 13.—External view of the chamber of habitation and two air-chambers of *Gomphoceras breviposticum whitfield.* It is possible that this species is a young form of *G. fusiforme.*

It is possible that *G. fusiforme* Whitfield and *G. breviposticum* Whitfield are of the same species. The differences in the chamber of habitation may be due to age. The shells are almost identical in size, in the depth of the air chambers, and the margin of the aperture.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis.; "Whitefish Bay, near Milwaukee."

Gomphoceras fusiforme Whitfield

(Figs. 11, 12)

Gomphoceras (?) *fusiforme* Whitfield: *Geology of Wisconsin*, Vol. IV (1873–79), p. 338, Plate XXVI, Fig. 16.

Description.—"Shell rather below a medium size, very moderately expanding from below upward to near the middle of the outer chamber, as seen on the type specimen, about which it again decreases to the aperture somewhat more abruptly than below. Section circular, or very nearly so, the slight flattening of the specimen probably due to compression. Septa not distinctly defined in the specimen, but apparently about one-sixteenth to one-twelfth of an inch apart, and but

slightly concave." [Septa 5^{mm} apart at the chamber of habitation, and 3^{mm} apart 3^{cm} from the chamber. Siphuncle marginal.]

This species resembles *G. tumidum* Hall of the Chemung shales of New York.

It is possible that this is an old-age form of *G. breviposticum*. For discussion on this point see description of that species.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis., especially abundant in the "hard layer;" "Whitefish Bay, near Milwaukee."

FIG. 14.—Exterior view of a remarkably well-preserved specimen of *Gyroceras clarkei* N. S., in which what appear to be traces of both transverse and longitudinal color markings are retained. The original is from the Public Museum, Milwaukee.

Gomphoceras sp.

(Fig. 8)

Description.—An almost perfect specimen of a large Gomphoceras, differs from other Milwaukee cephalopods in that it is subfusiform and has a large chamber of habitation which contracts slightly toward the aperture. Septa 3 or 4^{mm} apart near the chamber of habitation, but 9 to 10^{mm} apart 6.5^{cm} from the chamber. Transverse section apparently elliptical. The greatest diameter appears to be at about the tenth septum.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis.

Gyroceras eryx Hall, n. sp.

(Fig. 14)

Description.—Shell large, regularly coiled, forming a very open spiral, making about one and one-half volutions. Regularly enlarging from near the apex to the chamber of habitation. Oval or circular in transverse section. Apex unknown. Greatest diameter of the coil 17 cm.

Chamber of habitation comparatively short, and in one specimen appears to be contracted toward the aperture. Aperture not clearly shown, but apparently has a shallow hyponomic sinus on the convex side.

Septa numerous, regular, with straight transverse sutures which near the chamber of habitation are 9mm apart on the convex side, and 5mm apart on the inner side.

Siphuncle small, situated about one-third the diameter of the shell from the lower side.

What appear to be surface markings are preserved on the inner mold and show fine growth lines swinging backward and crossing the septa at an angle of about ten degrees. Fine irregular longitudinal lines which appear to be vestiges of color markings are also shown.

Locality.—Milwaukee Cement Quarry, Berthelet, Wis.

DISCOVERY OF CAMBRIAN ROCKS IN SOUTHEASTERN CALIFORNIA

N. H. DARTON[1]

During a recent trip in the desert region of southeastern California, I discovered an extensive series of fossiliferous Cambrian rocks in the vicinity of the Santa Fé Railroad. The locality is on the south end of a ridge known as Iron Mountain, 2 miles northwest of Siam Siding, in the eastern part of San Bernardino County. The rocks constitute the summit of the ridge and dip down its eastern slope. They lie on granite which rises several hundred feet up the western side. The adjoining country is a desert plain, but the ridge extends far to the northward. My opportunities for determining the structure and stratigraphy were limited, and only a partial section was measured. It comprises the following beds:

	Feet
Shales and sandstones	200+
Limestone	6
Gray shales	50
Limestone	8
Gray shales with few limestone and sandstone layers	250
Nodular limestone	25
Massive hard dark-blue limestone	50
Gray shales with calcareous sandstone layers	20
Gray sandstones and quartzites	500
Dark hard quartzites, conglomeratic at base	60
Granite	

Fossils were found in the limestone layers in the gray shales above the nodular limestone, and also in the gray shales below the 50-foot bed of dark-blue limestone. They consisted of fragments of trilobites and molluscs, which proved to be not specifically determinable, but Mr. C. D. Walcott believes them to be undoubtedly of Cambrian age, probably Middle Cambrian.

The contact with the granite is clearly exposed and was traced for about a mile. It is unquestionably a shore line and not a contact of

[1] Published by permission of the Director of the U. S. Geological Survey.

intrusion. Therefore the granites are of pre-Cambrian age. At one locality the granite is traversed by a dike of black basic rock on which the basal Cambrian conglomerates lie. As some of the granites of southern California are post-Paleozoic, it was of interest to find that the granite in Iron Mountain, at least, is of pre-Cambrian age.

In the vicinity of the gold mine, 2 miles southeast of Siam and almost in the line of strike of Iron Mountain, another high ridge consists of limestone and quartzite cut by a dark-colored, coarse-grained

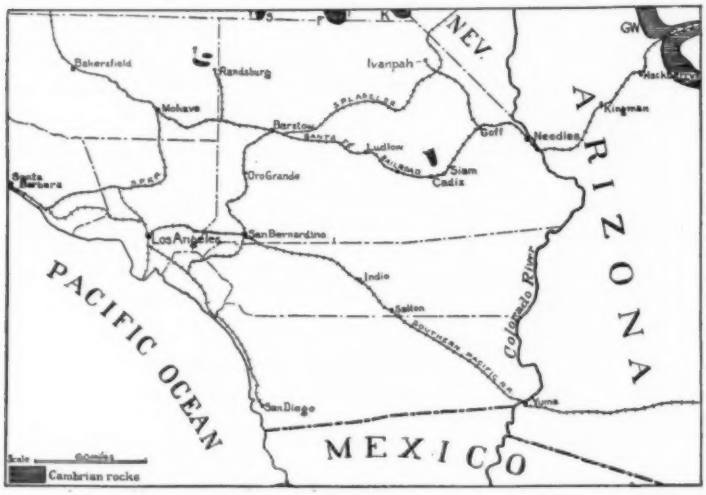


FIG. 1.—Sketch map of the southern California region showing occurrences of Cambrian rocks. GW, Grand Wash escarpment; K, Kingston Range; F, south end of Funeral Range; S, Slate Range.

granite. The exposure shows 200 feet or more of quartzite, overlain by greenish shale, capped by 800 feet of semi-crystalline limestone. No fossils were found, but some features of the limestone suggest that it may represent the Red Wall limestone of the Grand Canyon region 200 miles northeast. The quartzite lies on granite at this locality, but granite also cuts irregularly across the limestone, and apparently has caused its alteration.

The rocks above described are in the middle of a wide area of which the geology has never been studied. The location is shown in

Fig. 1, in which are also indicated the nearest occurrences of Cambrian rocks previously known. At GW is the Grand Wash escarpment on the western margin of the Arizona plateau traversed by the Grand Canyon of the Colorado. In this escarpment is the well-known succession of 1,000 feet or more of the Tonto (Middle Cambrian) sandstones and shales lying on pre-Cambrian granites and overlain by several thousand feet of Carboniferous limestones.

Cambrian rocks have been described by J. E. Spurr[1] on several ranges in the southern portion of Inyo County, extending to and slightly over the northern margin of San Bernardino County. These descriptions were based partly on his own observations and partly on notes of a trip made by Mr. R. B. Rowe. The most extensive areas which are in and near the Kingston Range (K, Fig. 1) were discovered by Mr. Rowe. The rocks here consist of over 1,500 feet of quartzites of various colors and limestone, sandstones, and shales. One mass of massive dark-blue limestone is mentioned. The rocks contain fossils at different horizons, some of which are stated to be lower Cambrian. They lie on gneisses and other crystalline rocks. In the southern end of the Funeral Range (F. in Fig. 1) there are about 2,000 feet of slates, limestones, conglomerates, and quartzites noted by Gilbert[2] and Campbell.[3] These observers found no fossils and Campbell suggests that the rocks may be of pre-Cambrian age. Mr. Spurr maps them as probable Cambrian. Some of the beds in Slate Range (see Fig. 1) and west of Randsburg are mapped as Cambrian by Spurr on the authority of H. N. Fairbanks,[4] who refers to them as "probably Paleozoic."

In the White Mountain Range, over 100 miles north, there are nearly 5,000 feet of sandstones, shales, quartzites, and limestones, in which Mr. Walcott[5] discovered an extensive series of Lower Cambrian fossils. In certain parts of the range the rocks are cut by great masses of intrusive granite.

In the Spring Mountain and Las Vegas regions, southern Nevada,

[1] U. S. Geological Survey, *Bulletin No. 208* (Washington, 1903).

[2] *U. S. Geographical Survey West of the 100th Meridian*, Vol. III, p. 170.

[3] U. S. Geological Survey, *Bulletin No. 200*, p. 14 (Washington, 1902).

[4] *American Geologist*, Vol. XVII, pp. 65, 149.

[5] *American Journal of Science, Third Series*, Vol. XLIX (1895), pp. 141–44.

Spurr[1] reports sandstones, limestones, and other rocks containing fossils probably of Middle Cambrian age.

Quartzites and crystalline limestones occurring just east of Oro Grande station believed to be Cambrian by Hershey[2] but no fossils were found in them.

[1] *Loc. cit.*, pp. 155, 165.

[2] *American Geologist*, Vol XXIX, p 288.

SOME NOTES ON SCHIST-CONGLOMERATE OCCURRING IN GEORGIA[1]

S. W. McCALLIE
Assistant State Geologist

The rather remarkable schist-conglomerate here described occurs in Lumpkin County, Georgia, about 2½ miles southeast of Dahlonega,

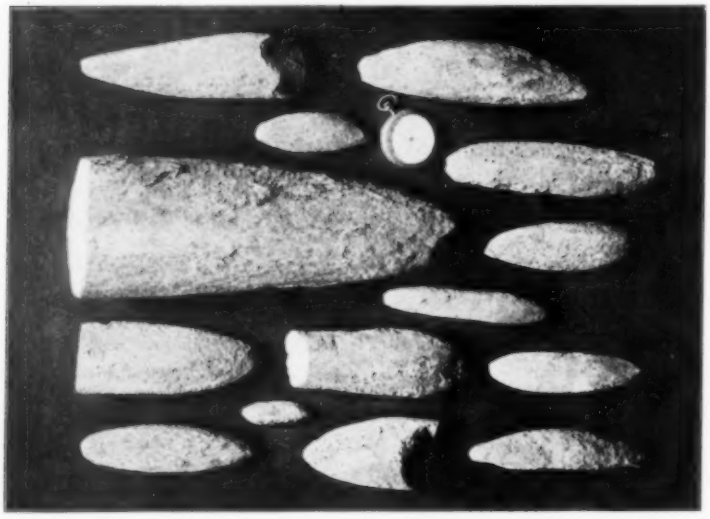


FIG. 1. — Stretched boulders weathered from schist-conglomerate, Lumpkin County, Georgia.

the county site. The best exposure is to be seen on the Dahlonega-Auraria public road at a point where the road traverses a narrow ravine along a small stream. The conglomerate here forms a number of low, disconnected bluffs on the south side of the road, and also occurs in the bed of the stream, where it forms a series of cascades. In passing the road, most persons would likely mistake the exposure for an outcropping of biotite-schist—a rock

[1] By permission of the State Geologist.

of frequent occurrence in the Dahlonega district. It is only by a close examination from different view-points that the true nature of the rock can be made out. Along a fresh cleavage plane the rock has every appearance of a biotite-schist with a comparatively small amount of quartz, while sections normal to the cleavage, or forming various angles therewith, reveal the presence of elongated bowlders and pebbles in greater or less abundance. The individual bowlders and pebbles are to be seen to the best advantage in the bed

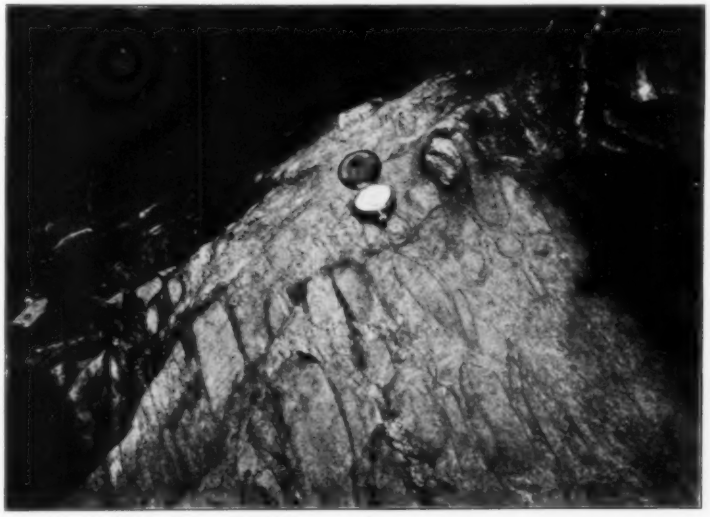


FIG. 2.—Schist-conglomerate, showing stretched bowlders, Lumpkin County, Georgia.

of the stream, where the surface of the conglomerate has been polished by the action of the water. They are also to be seen in considerable numbers in the residual clays on the hill slope, where they have weathered from the outcroppings of the conglomerate at higher elevations.

The bowlders and the pebbles are both quite variable in size, but they are always greatly elongated in the direction of the schistosity.

Some of the larger bowlders attain a length of three feet. They are usually flat, spindle-shaped, with the greater diameter near the center. In cross-section they are ellipsoidal, the major axis being from two to three times as great as the minor axis, while the lengths of the bowlders themselves in many instances appear to be from five to

FIG. 3.—Schist-conglomerate, showing boulders and pebbles greatly elongated, Lumpkin County, Georgia.

fifteen times their original diameters. Owing, however, to a joint structure of the conglomerate, developed at nearly right angles to the schistosity, only the less elongated bowlders are to be found entire in the residual clays, the longer ones being usually divided by the

joints into two or more divisions. The surface of the bowlders is generally more or less roughened and occasionally pitted, as if having been attacked by some dissolvent agent. Striations, corresponding in direction to the long axis of the bowlders, are sometimes noticed, but such markings are not common.

A microscopical examination of thin sections shows that the bowlders and the pebbles consist almost entirely of interlocking grains of quartz, the chief accessory mineral being mica, which makes

FIG 4 — Schist-conglomerate, showing joint structure, Lumpkin County, Georgia

up, apparently, only a fractional part of 1 per cent. of the entire mass. The quartz grains in some cases are slightly elongated in the direction of the longer axis of the bowlders, but the extent of the deformation is by no means sufficient to account for the elongation of the bowlders themselves. The matrix, binding the bowlders and pebbles together, is made up chiefly of biotite and quartz, the former mineral being the more abundant. Magnetite also occurs in more or less abundance in the matrix in the form of crystals arranged along certain well-defined lines.

The rocks associated with the schist-conglomerate seem to be highly metamorphic clastics and intrusives, the former being represented by biotite-schist and the latter by diorite-schist. The age to which these altered clastics belong is not definitely known. They are probably early Cambrian or Algonkian, but they may possibly be even more recent.

ON AN OCCURRENCE OF CORUNDUM AND DUMORTIERITE IN PEGMATITE IN COLORADO

GEORGE I. FINLAY
Colorado Springs, Colo.

Introductory.—The purpose of the writer in the present paper is to record the occurrence of corundum in association with dumortierite and sillimanite in the rôle of igneous minerals in pegmatite, near Canyon City, Colo. The pegmatite dike in question is acid, its mineralogy is that of a granite, and it stands in epidote schist near masses of granite along Grape Creek. Corundum was first noted in the dike by Mr. Eugene Weston, of Canyon City. The occurrence is recorded by J. H. Pratt in the paper cited below.[1] The facts point to the igneous character of the pegmatite dike. It is therefore of interest to find corundum, dumortierite, and sillimanite in it as possible original constituents of such an acid rock. The dike does not show signs of metamorphism.

The complex of rocks appearing at the north end of the Wet Mountains in Colorado, on which the Ordovician and later Paleozoic series rests unconformably, consists largely of schist and gneiss, cut by veins of pegmatite and by diabase dikes. The wall rock in which the corundum-bearing pegmatite vein stands is dark, fine-grained schist. Under the microscope apple-green pleochroic hornblende appears as the most abundant constituent. Quartz is in small grains. The feldspar is deeply kaolinized, with muscovite as an alteration product. Epidote and magnetite are abundant. Apatite and hematite occur sparingly. Dark biotitic granite appears in extensive masses near the locality in question. Microcline, acid plagioclase, quartz, and biotite, with zircon, apatite, magnetite, and secondary hematite, are its constituent minerals.

Occurrence in the field.—The vein of pegmatite is seen on the ridge between the Rocky Mountain Boy and Joker claims on Grape

[1] J. H. Pratt, "Mineral Resources, Abrasives," *U. S. Geological Survey*, 1901, p. 45; see also *North Carolina Geological Survey*, Vol. I (1905), p. 238.

Creek, seven miles southwest of Canyon City, Colo. The abandoned tunnel of the Rocky Mountain Boy bears N14E from it. The distance from the mine tunnel is about 100 yards. The United States landmark No. 6236 has been cut on the vein at the summit of the ridge. The vein is from 40 to 80 feet wide. It stands vertically in the schist, appearing as a knob where it crosses the divide. It strikes N46E, running down the hillside for some distance on either hand until it is covered by the rock slide of the lower slopes. Two prospect holes have been made on it above the Rocky Mountain Boy. Along the south wall against the schist are stains of copper, malachite, and it is near this wall that the corundum occurs most abundantly.

Macroscopic description.—In hand specimens glassy quartz, in grains an eighth of an inch across, is the most abundant mineral in the pegmatite. The corundum appears to favor association with the quartz. White sugary plagioclase is present, with rarer crystals of pink microcline. Two kinds of mica are prominent, one white, the other black and much more abundant. The plates are at times half an inch across. Muscovite and biotite are indicated by the axial angles. Corundum appears as a local constituent of the vein in hexagonal crystals which are often half an inch in diameter. The mineral is glassy, and of a clear blue color, but not good enough to be of gem quality. The basal cleavage is prominent.

Microscopic description.—Under the microscope quartz, with the minute needles referred to rutile, is seen to be as abundant as are the feldspars taken together. Microcline, and acid plagioclase, probably albite, twinned on the albite law with occasional pericline lamellae, are observed. No carlsbad twins were noted. The highest symmetrical extinctions measured were 9°. Muscovite is unusually prominent. The corundum resembles glassy quartz. Rectangular cleavage cracks parallel to the base are, however, prominent. Negative crystals of hematite are often seen in it. Basal sections give a uniaxial cross without the rings which appear in the field of view when the figure of quartz is examined. Dumortierite occurs in very perfect pointed prisms 1^{mm} in length by 0.03^{mm} in breadth. They are faint blue. At times they make up bundles of radiating needles; occasionally they show a parting parallel to (001). Large, more massive columnar aggregates are very strongly pleochroic, from

faint blue to bright smalt-blue. Dumortierite could not be observed without the aid of the microscope. Bundles of radiating needles of sillimanite are occasionally met. Zircon occurs rarely. Secondary hematite is at times conspicuous.

Pyrogenic character of the corundum.—Corundum is described by W. G. Miller[1] in granitoid rocks over wide stretches in the province of Ontario, Canada. It is present in syenite, in nephelite syenite, and in anorthosite. Professor A. C. Lawson has given the name plumasite to a dike rock made up of oligoclase and corundum from Plumas County, California.[2] The granite of Nannie's Mountain, near Yorkville, S. C., carries corundum.[3] Morozewicz describes the occurrence of corundum in pegmatite in the Ural Mountains, intergrown with orthoclase,[4] and again as standing in the place of quartz in granite at Mikolskaja Ssopka, Ural Mountains, Siberia. He names this rock corundum syenite, and declares his belief that corundum occurs in these rocks as an original pyrogenic constituent.

The remarkable occurrences of large amounts of corundum in close association with peridotite in North Carolina have been described by Dr. J. H. Pratt and Professor J. V. Lewis.[5] The view is held by these writers that much of the corundum in this association is an original constituent of the rock. The distribution of the corundum with reference to the peridotite masses is (1) peripheral, along the contact between the peridotite and gneiss; (2) in the peridotite masses in banded veins containing, besides corundum, the minerals chlorite, clinochlore, spinel, and enstatite; and (3) corundum occurring alone, inclosed by peridotite (dunite) at the Hayes Mine, Yancey

[1] W. G. Miller, "Economic Geology of Eastern Ontario," *Seventh Report, Ontario Bureau of Mines*, 1897 (Toronto, 1898), p. 213. See also W. G. Miller, "The Corundum Bearing Rocks of Eastern Ontario, Canada," *American Geologist*, Vol. XXIV (1899), p. 276.

[2] A. C. Lawson, "Plumasite, an Oligoclase Corundum Rock near Spanish Peak, Cal.," *Bulletin, Department of Geology, University of California*, Vol. III (1903), pp. 219–29.

[3] J. H. Pratt and J. V. Lewis, *North Carolina Geological Survey*, Vol. I (1905), p. 222.

[4] J. Morozewicz, *T. M. P. M.* Vol. XVIII, p. 215, 1898.

[5] "Corundum and the Peridotites of Western North Carolina." *North Carolina Geological Survey*, Vol. I (1905).

County, N. C. Such an association as that last mentioned, (3), was observed in but one locality. Here it is quite possible, in the light of the experiments made by Morozewicz, that the corundum is an original pyrogenic constituent, as suggested by Dr. Pratt. The other occurrences, (1) and (2), can hardly be regarded as anything but secondary alteration products in veins. They show at times a remarkable banded structure, and they are made up largely of the minerals of alteration.

T. H. Holland[1] in the *Geology of India* records the occurrence of corundum in a variety of rocks. While he states that the occurrence of this mineral "as a constituent of normal lavas in the form of tabular crystals characteristic of those obtained artificially by Morozewicz during the devitrification of a slag leaves no doubt as to the possibility of its free crystallization from an igneous magma, as is admitted for other simpler though commoner oxides," he does not admit that the occurrences which have come under his observation are other than accidental, in the sense that the excess of Al_2O_3 was contributed from some extraneous source, or influenced by some rock other than the matrix of the corundum. Thus at Karutakalaiyam, in Madras, corundum occurs "in a coarse feldspar rock," but only near its contact with an eleolite-bearing rock rich in Al_2O_3. Corundum in India occurs in association with basic rocks, but near pegmatite dikes; and, according to Mr. Holland, influenced by such intrusions. The occurrence of corundum with sillimanite imbedded in orthoclase in an acid rock near Paparapatti, Madras, is referred to the contact effects of veins of pegmatite on pyroxene granulite.

The pegmatite dike near Canyon City, Colo., does not show any structures in the field pointing to its having been sensibly changed by metamorphic processes. The arrangement of the constituent minerals is not such as we look for in a metamorphic rock like gneiss. The development of the mica plates is not that which we should expect in a schistose rock. Garnet was not observed. The minerals in the pegmatite are essentially those in the granite which is near at hand. In the dike they are not arranged in lines parallel to the walls, as they have been observed to be in pegmatitic veins or dikes filled

[1] T. H. Holland, *Geology of India*, p. 10.

"by cementation."[1] Bearing in mind that "under proper conditions water and liquid rock are miscible in all proportions,"[2] the criteria for judging between pegmatite dikes which originate by igneous injection, and those in which heated waters play a larger rôle than molten rock, must be chiefly those of structure. The pegmatitic dike in question, by reason of its eugranitic structure in the field, appears to be among those which deal chiefly in molten rock, and are not greatly charged with heated waters. It lies very near the granite mass along Grape Creek. It tapers rapidly as it runs up the ridge. It has sent off occasional stringers into the schist six inches or more in width, sharply marked off, as are injections of igneous rock into fissures in the form of dikes. These observations support the view that the great dike in question is near the igneous end of the pegmatite series. It would appear that the acid magma was in places uncommonly rich in alumina, and that the excess of Al_2O_3 over that required to satisfy the alkalies and lime for the formation of feldspars crystallized as the oxide corundum. The mineral does not appear as a filling of cavities in the pegmatite. Under the microscope it bears the same indigenous aspect as do the other constituents of the rock. No evidence was obtained such as would point to a replacement of pre-existent minerals by the corundum. It is fresh and clear, and does not show itself as an alteration product of some other mineral. There is nothing to make it plain that the corundum has resulted from some other aluminous mineral by dehydration attendant on metamorphism. It is difficult to reconcile its distribution in the rock with the assumption that the Al_2O_3 needed for it was gained by the working-over in the magma of included portions of the wall rock.

Chemical characteristics of the pegmatite.—The calculation of the analyses of persalanes for their norms frequently presents an excess of Al_2O_3 to be referred to corundum. In the corundum-bearing subclasses of persalane are found quartz felsite, granite, quartz keratophyre, the Uralose rocks described by Morozewicz under the names corundum syenite and corundum pegmatite, and the two

[1] C. R. Van Hise, "Treatise on Metamorphism," *Monograph 47*, U. S. Geological Survey, p. 723.

[2] *Ibid.*

analyses of kyschtymite falling in the perfelic order Siberare described by the same author. The present occurrence of modal corundum is one in which the rock is much more siliceous than are the rocks above mentioned in the corundum-bearing subclasses of the persalanes. From a quantitative study of its mineralogy it is placed tentatively in the order Columbare of Class I. It is domalkalic. Dumortierite is a basic aluminic silicate, $Al_8Si_3O_{18}$, with a part of the aluminium replaced by boron. It might reasonably be expected, therefore in a siliceous rock rich in alumina, as is the pegmatite vein near Canyon City. Dumortierite has been reported from a pegmatite vein in schist at Harlem, N. Y.,[1] and from Clip, Yuma County, Ariz. It has been found in similar occurrences near Lyons, France, and near Schmiedeberg, Silesia, as well as in gneiss at Tvestrand, Norway. The present occurrence seems to justify the view that for it corundum and dumortierite are original pyrogenic accessory constituents, and that in other igneous rocks these minerals may occasionally play the same part.

[1] For a systematic account of the reported occurrences of dumortierite see W. T. Schaller, *Bulletin 262*, U. S. Geological Survey, p. 91.

GLACIAL ROCK SLIDING

F. O. JONES

A geological curiosity in the shape of a displaced mass of rock resulting from ice-pressure during the glacial invasion has been partially uncovered in the Voight quarry, three miles north of Elmira, N. Y., and one-half mile south of Latta Brook ravine. Reference may be had to the Elmira sheet of the United States Geological Survey, but the contour lines represent the topography only in a general way.

The quarry is located in the face of a ledge which extends out some 300 feet from the main hill. At its southern end the cutting is only 37 feet deep, but the linear extent is nearly 400 feet. The bottom is about 35 feet above the valley level, making the present approximate height of the point 70 feet.

Massive sandstones form the bottom of the quarry, but they rapidly thin out, and the upper third is very largely composed of shale. This formation has received the local name "High Point sandstones."[1] The strata have a northward dip of about 50 feet per mile, and their position indicates that the axial inclination of the Elmira anticline, to which they belong, is fully as great eastward. Their position was, therefore, an important factor in the amount of pressure required to move the load.

The south side of the ledge is in the form of steps or small terraces, which remain as they were in preglacial times, and it is down over this serrated slope that the rock mass was shoved. Its present form is indicated much more clearly by the accompanying sketch than it could be by a detailed description. The base or shoe on which the slide occurred is a hard, blocky sandstone 12 inches thick, and it is chiefly owing to this fact that its character can be recognized.

Any attempt to delimit the slide must be largely conjectural, owing to the till covering. There are 50 feet of the basal sandstone in sight, and at one point 7 feet of shale and thin sandstones remain

[1] Museum Bulletin No. 81, *Watkins and Elmira Quadrangles* (Albany, N. Y., 1905).

in place on it, which would make 8 feet the minimum thickness. The width and length could hardly have been less than 100 feet each, or a total of 80,000 cubic feet. It is probable, however, that the original dimensions considerably exceeded the figures given.

A further evidence of the pressure exerted by the ice is a V-shaped fault in the face of the quarry 90 feet north of the slide. The first noticeable disturbance of the strata is just above a 6-inch sandstone. From that point the width of the fault regularly increases until the top of the exposure is reached (11 feet), where the width is 7 feet and the vertical throw about 20 inches. The 6-inch sandstone can be traced northward from the fault for more than 200 feet, and the

Voight's quarry, Elmira, N.Y., showing rock displaced by glacial ice. (Not drawn to scale).

whole amount of rock moved may have approximated half a million cubic feet.

Although rare, Voight's quarry does not contain the only preserved example of glacial rock-sliding. Another instance occurs in an old quarry at Pine Valley, some six miles farther north and on the western side of the valley. It was first noticed by Professor James Hall, and by him described as follows in the *Third Annual Report of the Fourth Geological District:*[1]

> At the last-named quarry I observed the singular fact of non-conformable strata, as yet the only instance noticed, and which various circumstances seem to render incredible. The strata are parts of the same mass, once continuous, the lower dipping south at an angle of four or five degrees, and the upper dipping north at about the same angle; and a short distance farther south the whole mass

[1] Albany, N. Y., 1839.

dips north. The only explanation that now offers is that at the time the rocks were subjected to the force which produced the undulations the upper part slipped over the lower and at this point partook of the elevation south, while the lower was affected only by the uplifting to the north.

It is not strange that Professor Hall should have failed to divine the cause of the stratigraphical disturbance since Pleistocene geology was then an undeciphered branch of the science. It is somewhat remarkable, however, that modern geologists have not commented upon this interesting phenomenon of the glacial invasion—interesting because it illustrates the great pressure sometimes exerted, and because it has a distinct bearing on that much-controverted theory of ice-erosion.

VALLEY DEPENDENCIES OF THE SCIOTO ILLINOIAN LOBE IN LICKING COUNTY, OHIO

FRANK CARNEY

Leverett classifies the drift of eastern Licking County as Illinoian. He says: The Illinoian deposits are much heavier in valleys than on uplands, and there is a marked sinuosity of margin to conform to the topographic conditions.[1] The observations described in this paper were undertaken in part to give closer definition to the extent of the topographic control to which Leverett refers. The paper attempts to show that the Scioto lobe on this part of its eastern margin, where it reached out over the more rugged topography of the coarser Mississippian and Pennsylvanian formations, was affected by valley dependencies. It is felt that a detailed study of the marginal areas may add to our knowledge of the exact shape of the ice-front at the time of its maximum extension.

MARGIN OF THE ILLINOIAN DRIFT

In central Ohio.—The general lobation of the Illinoian sheet, according to Leverett,[2] reflects the influence of great basins in the topography farther north, the Huron-Erie basin probably controlling its extension into the tract now drained by the Scioto River. That the extreme reach of the Illinoian ice in the southern part of the state—i. e., where it crosses the Ohio River in Brown County—is due to a combination of controls, seems likely.

Fig. 1 gives the results of Leverett's mapping of the Illinoian ice in Ohio. It appears that in one general locality on the eastern side of the Scioto lowland the ice manifested a tendency to protrude, as is shown by the curve southwest of Muskingum County; another evidence of this impulse is seen (Fig. 2), just north of this convexity, in the valley dependencies reaching beyond the body of the ice-field,

[1] *Glacial Formations of the Erie and Ohio Basins*, XLI Monograph, U. S. Geological Survey (1902), p. 222.

[2] *Ibid.*, p. 226.

described in the present paper. This later and more leisurely field-study gives greater prominence and exactness to this curve of local lobation first examined by Leverett.

In Licking County.—Save in the valleys, the Illinoian drift near its front is so attenuated that mapping it is a problem of elimination, or the careful study of the rather maturely dissected divide areas. The lesser details of topography in the marginal zone appear to have had slight influence on the outline of the ice-front, while obviously exercising a considerable control over the duration of the ice in its position

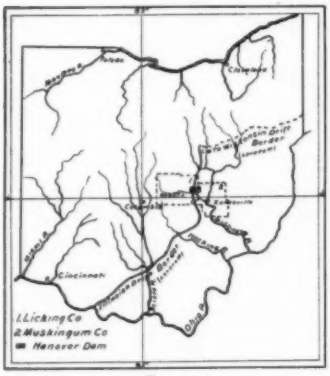


Fig. 1

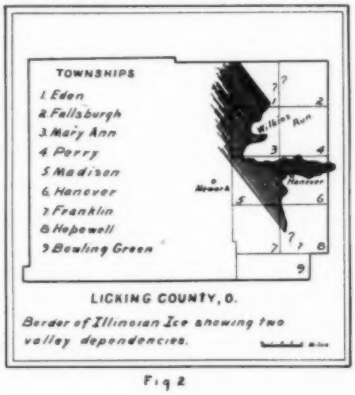
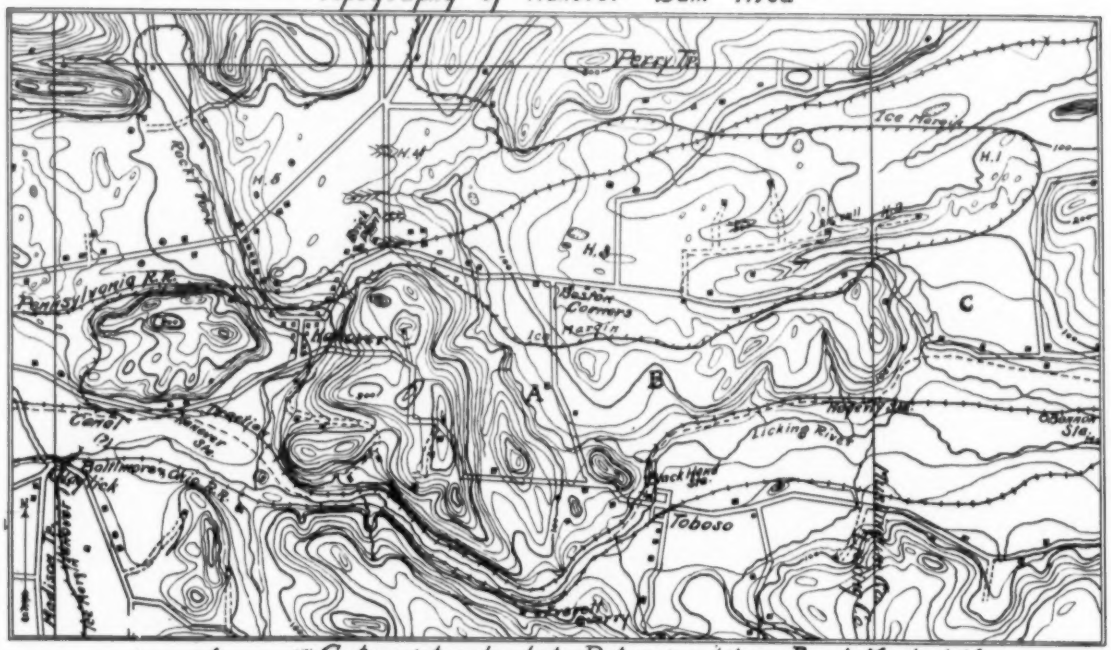


Fig 2

of maximum reach. This latter fact necessitates patient observation, particularly where the stratigraphy did not encourage differential-weathering effects previous to glaciation; it is evident that on slopes of heterogeneous rock structure facing the direction of ice-movement, benches of the more resistant formations, weathered into semi-detached spires and blocks,[1] would have suffered some from ice-work, even though the products of residual decay did not receive a noticeable admixture of glacial drift. But among the hills, where the rock structure is more uniform, and the weathered slopes correspondingly even, the absence of foreign material must be established before drawing the drift-line; and in these higher areas an unexpected localization of erratics surrounded completely by territory in which

[1] F. Carney, *Bulletins of Denison University*, Vol. XIII (1906), p. 124.

Topography of Hanover Dam Area



1 mi. Contour interval 20 feet – Datum is arbitrary Bench Mark at M.
>>>> Ice front channels – Fig. 8

the most diligent search has not revealed any evidence of glaciation is somewhat puzzling, but very convincing of the fact that the final demarkation of the glacial boundary is a problem of time.

In establishing the relationship of these valley dependencies of the Illinoian ice-sheet to the Scioto lobe, and in determining whether they are tongue-like extensions of the ice-mass at its period of greatest development, or at a later retreatal stage, three townships, Perry, Hanover, and Mary Ann, of Licking County, have been carefully

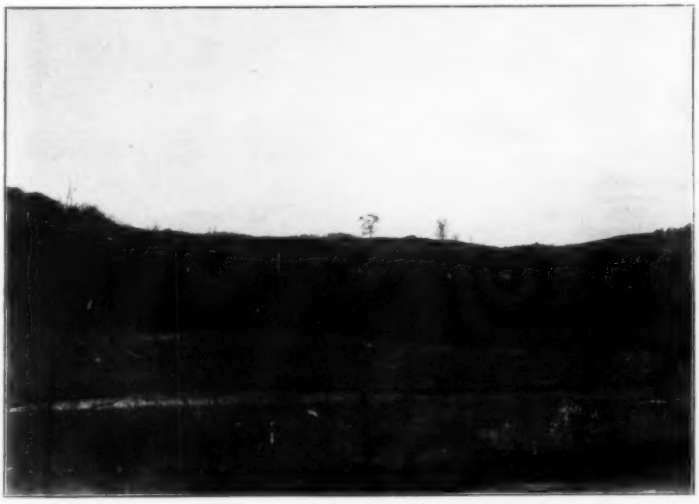


FIG. 4.—Looking south of east. The wooded area on the extreme left is rock, as is also the slope above the buildings on the right. The intervening ridge of drift marks the position of the ice-tongue that extended eastward from Wilkins Run.

studied, while like attention has been given to portions of adjacent townships. In valleys trending in general with the direction of ice-movement, the problem is one of distinguishing the unmodified drift from the deposits of entirely extra-glacial waters, and of determining the drift-covered portion of the valley walls.

It has been established that ice did not enter Perry township (Fig. 2) from the north or west,[1] and that the township was not glaciated

[1] F. Carney, *loc. cit.*, p. 124.

save for the presence of a lateral tongue reaching northward from the valley lobe that extended eastward into Muskingum County (Fig. 3).[1] Less than one-half of the next township west, Mary Ann, was covered by ice; this ice had a very irregular front. The conspicuous drift knolls at Wilkins Run are alluded to by Wright,[2] and by Leverett.[3] One of the most typical valley trains of this region was built into the mature valley southwest of Wilkins Run.

The southeast corner of Eden Township was not glaciated; but the front of the ice has not been traced in detail through this township, nor into Fallsburg. A small portion of the northeast corner of Madison Township was not covered by ice. The outline of the drift in Hanover Township is considered in the following section. Southward into Hopewell Township the margin of the ice has been traced in detail for only a short distance.

VALLEY DEPENDENCIES

At Wilkins Run.—A tongue of ice about one and seven-tenths miles long reached eastward from Wilkins Run. This village lies at one side of a mature valley which once embraced in its drainage the area east and north, the region now constituting the headwaters of the Rocky Fork; this defunct valley opened westward into the valley of the North Fork of the Licking River, and belonged to the ancient Newark River.[4]

[1] Since the government has not issued a map of this area, the writer, appreciating the difficulty that one not acquainted with the region would have in visualizing the topography described in the paper, has attempted to represent in contours the relief of the section about Hanover. No traverse work was done; county surveyor's maps were used for the highways and horizontal distances, an attempt being made to correct the grosser errors. It is felt, however, that the altitudes in reference to the arbitrary bench mark selected have been established with greater accuracy. For this purpose two aneroids were used; these instruments are of the same make, and for over a year have shown the same variation when together. During the progress of the field-work the aneroids were set the same at the bench each morning; the one kept at the bench was read every thirty minutes. The time at which readings were made on the other instrument in the field was recorded; the watchers were also set alike each morning. At night the field readings were corrected for the variations shown by the bench aneroid. Many critical points were checked several times.

[2] *The Glacial Boundary in Ohio*, Geological Survey of Ohio, Vol. V (1884), p. 755.

[3] *Loc. cit.*, p. 260.

[4] W. G. Tight, *Professional Paper No. 13*, U. S. Geological Survey (1903), p. 18.

This tongue-like extension of the ice pushed eastward to the point where the valley turns to the north; a tributary from the east which joins the major at its bend to the north, being in line with the feeding ice, was blocked also. The ice reached northward but a short distance beyond this angle; a few drift knolls mark this brief position. A halt of considerable duration was made after the ice had retreated to a position bringing the north side of the valley tongue directly across the valley; here it built a marginal ridge averaging 90 to 95

FIG. 5.—Moraine which marks the terminus of the Hanover valley dependency.

feet high, at no point lower than 70 feet, and about 500 feet broad at the base (Fig. 4). A terrace of similar development marks the outline of the ice against the walls of the valley elsewhere, except in front of the tributary valley, mentioned above, through which most of the drainage from the ice was led east to the Rocky Fork valley. It is evident that the Rocky Fork drainage had gained control of the mature valley long previous to its being occupied by this ice.

These moraine terraces, best developed on the south side of the valley, are very conspicuous. Commencing across the valley from

the hills mentioned by Wright,[1] a terrace of the aggradation type reaches half-way up the valley wall; it gradually descends eastward, where it becomes more irregular both because of initial distribution and of subsequent weathering. The line of demarkation between this drift and the upward slope is sharp.

The main body of ice, while the tongue reached eastward, maintained a position nearly north-south for a few miles each way from Wilkins Run. North of this place, so far as Mary Ann Township is concerned, the retreat of the ice-front appears to have been rapid, and there is no evidence that the valley lobe maintained intermediate positions; but the old valley becoming broader southwest of Wilkins Run encouraged a tongue-like extension of ice at the next halt of the ice-field; the well-developed valley train already mentioned was formed at this time.

At Hanover.—Here we have a much wider valley than the case just cited. The tongue of the ice reached about six miles eastward from the main body of ice. The maximum position of this valley dependency is marked by typical morainic topography (Fig. 5), with a contemporaneous deposition of drift against the side walls of the valley, which above the glacial débris are veneered with rock decay *in situ*. The line of demarkation between this drift and the valley wall is shown very conspicuously on the Hagerty farm southeast of the 216-foot well (Fig. 3). The drift, judged from surface appearance, especially east of the Muskingum County line, is rather bowldry; no very large bowlders were noted, but their fewness may be accounted for by the fact that the area has long been under cultivation.

This tongue-like extension of the ice maintained its distal position for some time, but in comparison with the duration of retreatal positions the period was proportionately brief. At the second halt the alignment of the drift suggests a tapering of the ice-tongue; this form, however, is not seen in the other halts (Fig. 3, *H*. 3, 4, etc.), because of the contraction that exists in the valley in the vicinity of Hanover. So long as the ice fed actively through this narrow part it broadened some in the wider segment of the valley beyond; only in this latter area should we expect to find evidence of tapering as the ice-movement weakened.

[1] *Loc. cit.*, p. 755.

Moreover, it should be noted that the distribution of the drift in this valley does not conform to the pattern usually normal to valleys[1] which encourage tongue-like extensions from the ice border in line with the direction of the deploying ice. The east-west valley passing Hanover is unusual in that it has a composite history, the most obvious feature of which, that it was formerly the course of a west-flowing stream, has been published.[2] The continuity of the south wall of the valley is broken by gaps at *A*, *B*, and *C* (Fig. 3), representing a change in the drainage-control of the region; the presence of these openings allowed free drainage, particularly in the case of *A* and *C*, from the southern side of the ice-tongue, thus removing much glacial rubbish that otherwise would have remained as a lateral terrace or ridge.

Furthermore, westward from Hanover the valley grows broader; at Newark, a distance of seven miles, it is about two miles between the rock walls. Consequently as the margin of the eastern side of the Scioto lobe assumed new positions in its decline—a long halt has been noted in the vicinity of Newark[3]—this valley dependency persisted.

The details of the drift south and southwest of Claylick have been studied for two miles, showing that the retreat of the main body of the ice was gradual, and apparently maintaining positions parallel to the convex margin mapped by Leverett.

SUMMARY

A study of the Illinoian drift in this broken topography of the coarser-textured and more resistant formations of the Mississippian and Pennsylvanian periods establishes the existence of tongue-like dependencies of the Scioto lobe reaching out into the eastward-trending valleys.

[1] R. S. Tarr, *Bulletins of the Geological Society of America*, Vol. XVI (1905), pp. 218, 219.

[2] F. Leverett, *loc. cit.*, p. 155; W. G. Tight, *Bulletins of Denison University*, Vol. VIII (1994), p. 47.

[3] F. Leverett, *loc. cit.*, Plate II.

Reviews

The Cause of Earthquakes, Mountain Formation and Kindred Phenomena Connected with the Physics of the Earth. By T. J. J. See. *Proc. Am. Phil. Soc.*, Vol. XLV (1907), pp. 274–414.

The typical propositions of this paper are the following:

The dynamical cause of earthquakes and volcanoes probably depends upon the explosive power of steam formed within or just beneath the heated rocks of the earth's crust chiefly by the leakage of the ocean beds. (Pp. 276, 277.)

The internal temperature of the earth is extremely high, with heated rocks quite near the surface, while the crust is fractured and leaky everywhere, and especially where the depth of the sea is greatest. The sea covers three-fourths of the earth's surface, and earthquakes are found to be most violent where the sea is deepest, and volcanoes most numerous on the adjacent shores. Could then anything be more probable than to suppose that both of these great natural phenomena depend simply and wholly upon the explosive power of steam which has developed in the heated rock of the earth's crust? (Pp. 278–80.)

The conclusions are as follows, from which the geologist who has some accurate knowledge of earthquakes, volcanoes, mountains, and geophysics may decide whether he cares to follow up these views in the paper itself:

1. We have seen that deposits of sediment on the continental shelves could not possibly produce anything but the most gradual increase of weight on these portions of the earth's crust; and since such rocks as marble are proved to be fluids of great viscosity, and therefore capable of slow secular bending without rupture, we may feel sure that any stresses thus arising in the earth's crust would be relieved by gradual yielding, and that no violent earthquake shock could ever arise from such a cause.

2. The theory that earthquakes are due to fracture and slipping of rocks is disproved by the great depth (ten to twenty miles) at which world-shaking earthquakes are found to originate, and by virtue of the fact that they come not from a point nor from a line, but from an area; and moreover earthquakes follow the seashore, seldom occurring far inland, and never in desert countries, though abundant in the bed of the ocean.

3. It therefore follows that earthquakes must depend upon explosive forces within or just under the earth's crust, and frequently spread over a considerable area, and the preponderance of disturbances in the sea along the shores of continents shows that the forces depend in some way upon the sea water. These explosive forces can be best studied in connection with the eruption of volcanoes,

since volcanic outbreaks are also accompanied by earthquakes often felt over large areas.

4. Not all earthquakes lead to eruptions, but if the shocks in a given region cease on the eruption of a neighboring volcano, we may feel sure that the forces producing the eruption also produced the antecedent earthquake shocks felt by the surrounding country.

5. That steam is the cause of volcanic eruptions is proved by the distribution of active volcanoes about the seashores and by the innumerable eruptions which occur in the depths of the ocean, whereas such vents always die out inland; and moreover by the fact that of the vapors emitted from volcanoes 999 parts in 1,000 is estimated to be steam, the remaining one-thousandth part being by-products incidental to the moisture and high temperature.

6. The *vera causa* of volcanic action and of certain earthquakes thus established for some particular cases must be held to be the universal cause in all cases whatsoever, according to Newton's rule of philosophy.

7. The heaving of steam accumulating within or just beneath the earth's crust is therefore the true cause of all world-shaking earthquakes, and volcanic outbreaks occur only when an outlet is forced through to the surface, which usually happens in mountains, where the earth's crust is already badly fractured and upheaved.

8. When the subterranean steam pressure becomes great enough to shake the earth's crust, it naturally moves at the nearest fault line, where the rocks are broken, *but the movement observed is the result, not the cause of the earthquake*.

9. Volcanoes are particular mountains blown open by steam pressure under the throes of earthquakes (cracks in the rocks appear to be the beginning of some few volcanoes), and since all volcanoes blow out pumice and ashes, these materials must be held to exist in all mountains, and are made by the inflation of molten rock with steam and other vapors.

10. Any mountain peak, therefore, is capable of becoming a volcano if the subterranean steam pressure be sufficiently powerful to break open an orifice. But orifices close up and volcanoes die out inland and elsewhere if the supply of steam is inadequate to keep open the vents upon which the activity depends. Even if stopped up for a time, later heaving of the earth may give the volcano renewed activity, and when the mountain has been dormant for a long time it is found that the violence of the eruption is greatly increased. The violence of the subterranean pressure in such a case approaches that of a region which has no vent at all, and hence we see why earthquakes in non-volcanic regions frequently become so terrible, because the forces accumulate to frightful fury before any relief whatever is afforded, and the result is a most terrible earthquake.

11. The mountains are formed by the injection of steam-saturated lava under the coast, which breaks the overlying surface rocks and gives rise to a ridge parallel to the sea. This is why all mountains are formed parallel to the seashores.

12. By continually injecting the land with lava from under the bed of the sea the coast is raised and the mountains upheaved, and some of them usually break out into volcanoes; while at the same time the support of the sea bottom is undermined by the thinning-out of the fluid substratum, and at intervals the bottom sinks down to restore stability.

13. The sinking of the sea bottom in this natural process of earthquake injection of the land is the cause of that class of sea waves found to follow violent earthquakes, in which the water first withdraws from the shore and then returns as a huge wave. Those waves noticed to rise suddenly without previous recession of the water usually are due to submarine upheavals and eruptions in the bed of the sea.

14. Islands are built up by injection from the sea, and hence have their mountains as veritable backbones, because the injection is symmetrical from both sides. In many cases the sea bottom is thus undermined and finally sinks down, making a hole beside the island, or a trench. The fact that all islands are not accompanied by such sinks is no argument against the theory, because the subsidence has not always taken place; it is the occurrence of even a considerable number of such sinks beside islands which proves the validity of the theory. Such intimate associations between elevation and depression could not be the result of chance.

15. In the repair of ocean cables broken by earthquakes, subsidence of the sea bottom is frequently found to follow these disturbances. This is a direct observation of the above effects in certain cases which are established by actual measurement, the subsidences frequently amounting to hundreds of fathoms.

16. The sea bottom does not subside without the lava under the crust being forced out into some other place, as into islands, submarine ridges, or shores; none of this movement is due to the secular cooling of the earth, but is all to be explained by the undermining effect of steam accumulating under the earth's crust.

17. Mountains in the interior of a dry country, as the Rocky Mountains in Colorado, exhibit no important movements, while those on the coast, like the Andes, are always heaving. This shows that the sea is the cause, and not the secular cooling of the globe, which is wholly insensible.

18. The only countries which are free from earthquakes are the deserts, and therefore practically uninhabitable; there is accordingly no escape from earthquakes, and buildings designed for permanency should be framed to withstand them without material injury.

19. While in the long run the elevation of the land predominates, there is also subsidence, due to the non-occurrence of the forces in certain regions beneath the crust. It is idle to deny these oscillatory movements of the crust, and many good illustrations of both are clearly established. Every island which is thrown up in the sea is a witness to one of the most general laws of nature.

20. As water is taken up in the crust both in the crystallization of rocks and

in the processes of earthquake movements, and only a part of this vapor is restored to the surface through volcanic action, there is a secular desiccation of the oceans, but the process is excessively slow and not certainly recognizable during the historical period, though a part of the lowering of the strand line in later geological ages is no doubt traceable to this cause.

21. The elevation of the plateaus depends on the same cause which upheaved the mountains; and all plateaus, like the mountains, are underlaid with various forms of pumice, which accounts for their feeble attraction as shown by geodetic observations.

22. No doubt various chemical changes go on under the earth's crust where the water has penetrated the lava and the steam becomes superheated, but the predominance of water vapor in volcanoes shows that the other gases are only by-products, incidental to the moisture and great heat. Dissociation of water vapor is one of these effects.

23. The details of mountain structure admit of explanation on the present hypothesis, while heretofore no such explanation was forthcoming. A theory which accounts for the position of the ranges relatively to the sea, the slopes of the ranges, and the side spurs, and the relation of mountains to earthquakes and volcanic phenomena, should have a strong claim to acceptance. This theory was partially foreshadowed by the Arabian astronomer Avicenna, in the tenth century of our era.

24. The theory of the penetration of sea water into the crust of the earth and its connection with volcanoes and earthquakes dates back to Lucretius and Aristotle, while the upheaval of the land is distinctly announced by Strabo. We have, therefore, been simply verifying and extending the impressions of the ancients formed from the general aspects of nature long before the sciences had become exact. (Pp. 403–7.)

It is only fair to Avicenna, Lucretius, Aristotle, Strabo, and other distinguished authors quoted in this paper, to remark that they are not to be held responsible for all of the assertions of putative fact and physics with which their views are associated in this paper.

T. C. C.

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1. *Some Additions to the Carboniferous Terrestrial Arthropod Fauna of Illinois.* By A. L. MELANDER. (*Journal of Geology*, Vol. XI, No. 2, February–March, 1903, pp. 178–98, Plates V–VII.)
2. *Some New Structural Characters of Paleozoic Cockroaches.* By E. H. SELLARDS. (*American Journal of Science*, Vol. XV, April, 1903, pp. 307–15, Plates VII, VIII.)
3. *Discovery of Fossil Insects in the Permian of Kansas.* By. E. H. SELLARDS. (*Ibid.*, Vol. XVI, October, 1903, pp. 323–324.)

4. *Zur Phylogenie der Hexapoden.* By ANTON HANDLIRSCH. (*Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien*, Mathematisch-naturwissenschaftliche Klasse, Vol. CXII, 1903, pp.1–23.)

5. *Eine neue Blattinaria aus der Oberen Steinkohlenformation* (Ottweiler Schichten, Rheinpreussen). By FERNAND MEUNIER. (*Jahrbuch der Königlichen Preussischen Geologischen Landesanstalt und Bergakademie*, Vol. XXIV, No. 3, 1903, pp. 454–57, Plate XVIII.) (1904)

6. *Les insectes houillers de la Belgique.* By ANTON HANDLIRSCH. (*Mémoires du Musée royal d'Histoire naturelle de Belgique*, Vol. III, 1904, pp. 1–18, Plates I–VII.)

7. *Über einige Insektenreste aus der Permformation Russlands.* By ANTON HANDLIRSCH. (*Mémoires de L'Académie impériale des Sciences de St-Pétersbourg*, Série 8, Classe physico-mathématique, Vol. XVI, No. 5, 1904, pp. 1–7, with one plate.)

8. *A Study of the Structure of Paleozoic Cockroaches with Description of New Forms from the Coal Measures.* By E. H. SELLARDS. (*American Journal of Science*, Vol. XVIII, August–September, 1904, pp. 113–34, and 213–27, Plate I and 37 text figures.)

9. *Un Nouvel Insecte Fossile du Carbonifère de Commentry.* By AL. N. AGNUS. (Rev. Scientifique du Bourbonnais et du Centre de la France, Feb.–March, 1904, pp. 39–43; with one text figure.)

10. *Palæoblattina douvillei Brongnt.* By AL. N. ANGUS. (*Ibid*, April, 1904, pp. 85–86.)

11. *Revision of American Paleozoic Insects.* By ANTON HANDLIRSCH. Introduction by CHARLES SCHUCHERT; translated by LUCY P. BUSH. (*Proceedings of the U. S. National Museum*, Vol. XXIX, 1906, pp. 661–820.)

12. *Die fossilen Insecten und die Phylogenie der recenten Formen.* By ANTON HANDLIRSCH. Lieferungen I–IV, with 36 plates. Leipzig: Wilhelm Engelmann.

13. *Types of Permian Insects* . By E. H. SELLARDS. Part I, Odonata. (*American Journal of Science*, Vol. XXII, September, 1906, pp. 249–58; text figures 1–8.)

14. *Geological History of Cockroaches.* By E. H. SELLARDS. (*Popular Science Monthly*, March, 1906, pp. 244–50.)

15. *Haben die Paleozoischen Blattiden im Hinterflügel ein Praecostalfeld?* By DIETRICH V. SCHLECHTENDAL. (*Zeitschrift für wissenschaftliche Insektenbiologie*, Vol. II, March, 1906, pp. 47–50.)

16. *The Wing Veins of Insects.* By C. W. WOODWORTH. (*Technical Bulletins*, California Agricultural Experiment Station, Vol. I, 1906, pp. 1–152.)

1–5. Melander's paper is largely systematic. Two new genera of Hexopoda are described, *Petromartus* and *Protodictyon*, and one new genus of Arachnoidea, *Hadrachne*. The arachnid and insect material from the Carboniferous of Illinois contained in the Walker Museum of the University of Chicago, including two specimens from the Chicago Academy of Science, is identified and listed, and the type specimens are indicated. The classification of insects proposed by Scudder is followed. Sellards identifies the fossils previously known as *Dipeltis*, and referred by Packard and others to the Crustacea, as the nymph stages of cockroaches, and gives also a description of additional nymph and adult cockroaches, including a new genus of very large cockroaches, *Megablattina* (Sellards, non Brongniart; changed later to *Archoblattina*). The presence of an ovipositor is recognized on certain fossils identified as nymph cockroaches. The second paper by Sellards reports the discovery of insects in the Kansas Permian. The comparatively rare occurrence of insects in the Permian deposits is mentioned. The lack of definite record of insects from deposits older than the Carboniferous is noted. Handlirsch's paper is concerned with the Hexopoda in general, and proposes a revised classification for the group as a whole. The Hexopoda in this classification fall into four classes: Collembola, Campodeoidea, Thysanura, and Pterygogenea. Thirty-four orders are recognized, twenty-eight of which (grouped under eleven subclasses) are referred to the Pterygogenea. The Paleozoic insects are passed in review, and their place in the proposed classification, is indicated. Meunier gives a description of a new Coal Measure cockroach referred to the genus *Etoblattina* (*E. pygmaea* n. sp.).

6–10. The insects known from the Coal Measures of Belgium are referred by Handlirsch to fifteen genera, twelve of which are described as new. The insects described are regarded as representative of four orders, three of which—Paleodictyoptera, Megasecoptera, and Protorthroptera—are exclusively Paleozoic, while the fourth, Blattoidea, continues to the present. Eleven genera of insects are recognized from the Russian Per-

mian, nine of which are described as new. Three genera are referred to the Ephemerids, and one doubtfully to the Perlidae. The group Paleohemiptera is proposed for two genera, *Presbole* and *Scytinoptera*, regarded as ancestral to the Hemiptera. Mantidae-like forms are represented by the genera *Paleomantis* and *Petromantis;* the Blattoidea are represented by two genera, *Limmatoblatta* and *Aissoblatta*. Sellards regards the Paleozoic, Mesozoic, and modern cockroaches as making up a group of superfamily rank under the order Orthoptera, for which the term "Blattacea" is proposed. The body and wing structure of Paleozoic cockroaches is described, and the lines of specialization are discussed. In the first of the papers listed Angus described a new cockroach, *Etoblattina Gaudryi*, of which one hind wing, lacking the anal area, and the two front wings are preserved. The second paper by this author records a reexamination of the supposed Silurian fossil insect. *Palæoblattina Douvillei*, with the conclusion that this fossil does not represent an insect but pertains to the trilobites, and is in fact a part of the genal angle of one of the Asaphidæ.

11–16. Nine orders are regarded by Handlirsch as present in the American Paleozoic, as follows: Palædictyoptera, Protodonata, Megasecoptera, Hadentomoidea (new order), Hapalopteroidea (new order) Mixotermitoidea (new order) Protorthroptera, Protoblattoidea (new order,) and Blattoidea. Of these the first eight are regarded as being replaced in later deposits by other orders, the Blattoidea alone having continued to the present time. Twenty-five genera are referred to the Paleodictyoptera, seventeen of which are new. Two Protodonate genera are recognized from the American Carboniferous, *Paralogus* Scudder and a new genus, *Palætherates*. Two American genera, *Rhaphidiopsis* Scudder and *Adiaphtharsia* gn. n, are referred to the order Megasecoptera. The new order Hadentomoidea is based upon a single specimen, *Hadentomum americanum gn. sp. n*, from the collection of Mr. Daniels. The new order Hapalopteroidea includes but one American specimen, of which one front wing only is known. The provisional new order Mixotermitoidea is based upon two genera, *Mixotermes* from Saxony and *Geroneura* from New Brunswick. The Protorthoptera embrace a series of forms transitional between the Palædictyoptera and the Orthoptera. Sixteen genera are referred to this order. The Protoblattoidea are considered transitional between the Palædictyoptera and the Blattoidea. Thirteen genera are referred to this order. An entirely new grouping of the cockroaches is adopted. The Paleozoic representatives of this order are grouped into eleven families, ten of which are here established as new. Eighty-nine genera are recognized, sixty-nine of which are described as new. A table

prepared by Mr. David White accompanies the paper, showing the geological horizon as determined by paleo-botany and stratigraphy of the insect-bearing localities of the American Carboniferous.

"Die Fossilen Insekten," the second title of this year by Handlirsch, is intended to serve as "Ein Handbuch für Paleontologen und Zoologen." The fossil insects are treated chronologically by periods. No insects are recognized from deposits older than the Upper Carboniferous. The introductory part of the publication contains a synopsis of the orders of recent insecta. The Carboniferous insects are described in parts I, II, and III to p. 343. Permian insects follow (pp. 344 to 393). Mesozoic insects occupy the remainder of part III and IV. The remaining parts to be issued will complete the treatment of Mesozoic and Cenozoic forms in order. All known fossil Hexopoda are to be included in this work, and the described specimens so far as possible illustrated.

Sellard's paper on Odonata is Part I of a paper discussing the leading types of Permian insects. A new genus of Odonates, the first of this group obtained from the Permian, is described. The conclusions reached from a study of the Permian Odonates, and from a comparison of these with the Coal Measure forms, are that the wing venation of Paleozoic dragon-flies is not fundamentally different from that of modern dragon flies, as believed by Scudder, and that the Paleozoic dragon-flies are not to be separated as an order from Mezozoic and modern dragon-flies, as is done by Handlirsch, Three suborders are recognized for the order Odonata; Protodonata. Zygoptera, and Anisoptera. The second paper by Sellards is a résumé of the geological history of the cockroaches. Von Schlechtendal regards the vein in the hind wing of certain Coal Measure cockroaches, interpreted by Sellards as the costa, as being in reality the subcosta. Woodworth's paper on the wing veins of insects contains critical remarks on the venation of the wings of the better-known families of Paleozoic insects.

E. H. SELLARDS

The Place of Origin of the Moon—The Volcanic Problem. By WILLIAM H. PICKERING. *Journal of Geology*, Vol. XV, January–February, 1907, pp. 22–38.

To many geologists the arguments of this paper will appear to need no refutation and, if published in any other than a leading geological periodical, would not call for comment. There is danger, however, that by not formally presenting the contrary side of an argument, a greater credit and authority may be given to certain views by those in other branches of science than is warranted. It is because this article is of a nature which

may lead to its being widely quoted by those not pretending to pass independent judgment upon the problem, that the following reply is written.

In 1879 Professor George H. Darwin gave cogent reasons for thinking that originally the moon was much nearer to the earth than it is at present, and considered it probable that the earth and moon at one time constituted a single mass, though this conclusion was admittedly in the nature of an inference from the preceding. As Professor Pickering states, this conclusion has been accepted by the great majority of astronomers, although many of the geologists do not view it with favor. Accepting this hypothesis as to the origin of the moon, the author states:

> When the Earth-Moon planet condensed from the original nebula, its denser materials collected at the lower levels, while the lighter ones were distributed with considerable uniformity over its surface. At the present day, we find the lighter materials missing from one hemisphere. The mean surface density of the continents is about 2.7. Their mean density is certainly greater. We find a large mass of material now up in the sky, which it is generally believed by astronomers formerly formed part of our Earth, and the density of this material, after some compression by its own gravity, we find to be 3.4, or not far from that of the missing continents. From this we conclude that this mass of material formerly covered that part of the Earth where the continents are lacking, and which is now occupied by the Pacific Ocean. In fact, there is no other place from which it could have come.
>
> Who it was that first suggested that the Moon originated in the Pacific is unknown. The idea seems to be a very old one. The object of the present paper is to find what support for this hypothesis is afforded by the results of modern science, when examined both qualitatively and quantitatively. (P. 30.)

All will agree that the hypothesis is a very interesting one and worthy of the space given to it, and, even if opposed by very strong objections, is still of value as a hypothesis in the absence of positive knowledge as to the age and ultimate origin of the ocean basins. It must be concluded, however, as shown in these two paragraphs as well as many others in the article, that the author has not only failed to look up and to give credit to the originator of the hypothesis, which is here duplicated in many details, but has treated many phases of the subject with a positiveness and superficiality which cannot commend themselves to careful students of the subject. This is in marked contrast to the cautious treatment of the hypothesis by its originator, Osmund Fisher, in his initial statement of it entitled, "On the Physical Cause of the Ocean Basins," *Nature*, Vol. XXV (1882), p. 243, or in his reprint of it as A Speculation on the Origin of Ocean Basins, chap. xxv, *Physics of the Earth's Crust*, pp. 336–41, 379–81 (second edition, 1889).

The hypothesis appeals to the imagination, and at first thought appears to offer a striking explanation of both the shape and depth of the ocean basins. There are, however, certain assumptions involved in this restatement of it which are not clearly indicated as such, and the difficulties are dismissed without serious treatment. It is to call attention to these, as well as to give credit to the original papers on the subject, that this review and criticism is written.

First, no discussion is given of the possibility that the interior density of the earth may be largely due to the gravitational compression of ordinary rock material, since Professor Pickering states:

> The specific gravity of the Earth as a whole is 5.6. That of the surface material ranges in general between 2.2 and 3.2, with an average of 2.7. The specific gravity of the Moon is 3.4. This indicates clearly that the Moon is composed of material scraped off from the outer surface of the Earth, rather than of matter obtained from a considerable depth. At the same time, the specific gravity 3.4 indicates that the layer of material removed had an appreciable thickness. (P. 24.)

Nothing is really known as to the limits of the compressibility of rock under pressures of millions of pounds per square inch, allowing the alternative hypothesis to be equally assumed, that the earth may be largely made up of material which would not have a specific gravity of much, if any, over 3, if free from subcrustal pressures. Following this assumption, the moon may have been abstracted from any part of that mass, and at any time before the present relation of heavier oceanic and lighter continental crustal segments originated. The continents may then have subsequently come into existence according to any one of a number of hypotheses, such as proposed by Chamberlin or others. As the moon's mass is but one eighty-first that of the earth, its radius but a fourth, and gravity at its surface but one-sixth, it is seen that the material of the moon would suffer comparatively little compression even in its deeper parts, while its outer parts may consist of highly cellular rocks.

Second, this hypothesis rests upon the doctrine of the perpetual existence of the present forms and relations of the continental platforms. This is passed over with the statement that "it is the general opinion among geologists that the continental forms have always existed—that they are indestructible" (p. 28).

From the early advocacy of J. D. Dana, this may be called an American view, and represented a wholesome return from previous untrammeled speculations regarding the interchangeability of ocean basins and continental platforms. That Dana himself, however, came to a belief in a

liberal interpretation of this doctrine might have been easily determined by consulting the last edition of his manual (pp. 737, 1019), where it is seen that he accepts, as probable, former extensions of land in the Southern Hemisphere by which all of the now isolated land masses were connected. That a present belief in the strict permanence of the continental outlines is not shared by many geologists, especially by Europeans, is indicated by the paleogeographic maps in many books and articles, among which may be singled out the *Traité de Géologie* by A. de Lapparent (1911 pages; fourth edition, 1900).

Such maps are largely based upon paleontological evidence from many groups of animals and plants, and consequently appeal most strongly to the paleontologist, but that there is structural evidence for the view of former extensions of the continental platforms beyond their present limits may be gleaned from the monumental work of Suess, *Das Antlitz der Erde.*

In view of these statements, it may be said that it is the opinion of many well-qualified geologists that, while no large areas of oceanic basins have been uplifted and added to the continental platforms, there has been, on the contrary, an intermittent but progressive continental fragmentation through geological time by which land masses, most notably Antarctica, have been isolated and reduced in size, and the area of the oceanic basins correspondingly increased. The consequent enlargement of volume of those basins has tended to drain the shallow seas from the continental platforms and cause an intermittent but progressive emergence of the lands. Relative vertical movements of the oceanic segments and erosion of the lands have, however, also been major factors further complicating the result. The only known limitations to such changes of continental relations appear to be given by the general maintenance through geological time of the critical relations of the sea-level to the continental surfaces, and if, as seems probable, the volume of sea-water has increased through time, the area of the continental ptalforms may, in somewhat like measure, have decreased. These views affect the present hypothesis of the place of origin of the moon in two ways: by indicating that the Atlantic and Pacific may not always have possessed their present forms; but further, and more importantly, that the causes of the existence of ocean basins and continental platforms are not to be found alone in a primal cause no longer acting, but, to a considerable extent at least, to still acting and persistent causes.

Interesting consequences of certain suggestions put forth may be seen by comparing the last paragraphs on pages 32 and 33 respectively. The logical conclusion from these is that the ocean basins, formed by the break-

ing away of the moon, may not have existed until the end of the Paleozoic, with the result that, granting the present volume of sea-water, a universal ocean, averaging 10,400 feet deep, previously covered the whole earth. How, under such conditions, there came to be any sediments in the Appalachian geosyncline from a land "of continental proportions" the author does not attempt to explain.

Again, on page 31, the basic nature of the Hawaiian lavas is explained as a consequence of the removal of the lighter acid crust from the ocean basins to make the moon. It is easy to see how on this hypothesis the author would account for the enormous basaltic outpourings which have taken place over the surface of the continents, but it would be interesting to have his explanation of the fact that in Washington's tables of chemical analyses of igneous rocks the only analysis reported from Kerguelen Island gives a phonolite with 58.2 per cent. of silica and 12.0 of alkalies; the only one from Gough's Island a trachyte obsidian with 61.2 per cent. silica and 12.4 of alkalies; the only two from Ascension Island are trachyte and obsidian, the former with 71.0 per cent. of silica, the latter with 72.7.

The second part of the article, entitled "The Volcanic Problem," does not seem to have any very clear or close relation to the first part on the "Place of Origin of the Moon."

JOSEPH BARRELL

Essentials of Crystallography. By E. H. KRAUS. Ann Arbor, Mich.: Geo. Wahr. Pp. x+162; 427 figs. in text.

In the words of the preface, this book is "intended for beginners and aims to present the essential features of geometrical crystallography from a standpoint which combines the ideas of symmetry with those of holohedrism, hemihedrism, etc." All the possible crystal forms are discussed with the important classes pointed out.

A bibliography of forty-one titles of important reference books and articles is at the beginning of the book. This is followed by a sixteen-page general discussion of the properties of crystals, their arrangement into systems, the symbols used, the symmetry, and tractional forms. The systems are then taken up in order, beginning with the cubic and following through to the triclinic. The relations of axes, symmetry, and possible classes are taken up with considerable care in each system.

Compound crystals, with a full discussion of the laws of twinning, forms the last chapter, and is followed by a concise tabular classification of the classes, showing at a glance the planes, axes, and centers of symmetry, the possible forms, and the representatives, when known, of each class.

All of the illustrations are in orthographic projection, crystal projections being purposely omitted. The relations of the classes in each system are well brought out by tables and diagrams. The systems of notation of Weiss, Naumann, and Miller are used throughout the book in parallel columns, giving at a glance the relations between them. The classification of Groth is followed in the reverse order.

The book seems well suited to its purpose, and puts in a concise and compact form that part of its subject which is absolutely essential for an understanding of crystallography.

J. C. J.

Das Berneroberland und Nachbargebiete, specieller Theil. By A. BALTZER. Berlin: Borntraeger. Pp. 330, with 74 figures, and a map of the routes.

A series of European geological guidebooks is now being published by the Gebrüder Borntraeger in Berlin. Ten of these, devoted to the Elbe valley near Dresden, Mecklenburg, Bornholm, Pomerania, Alsace, Riesengebirge, Schonen, Campania, Italian Alps, and the Alps of Eastern Switzerland, are already out. The latest guide, that of the Bernese Oberland, is in two volumes, the first of which, describing special detailed routes, has recently appeared; the second volume, devoted to more general topics, including stratigraphy, formation of the mountains in general, a section upon the modern tectonics, the Aarmassiv, and the diluvial Aargletscher, is soon to follow. The chief attraction of this work lies in the field of tectonics, and as this obtrudes itself upon the traveler, it is here brought into the foreground and explained by the aid of profile sections. Long lists of rocks and minerals which may be studied to better advantage in museum collections are here avoided.

The general plan of the booklet is to follow one principal route through the Bernese Oberland proper, from which there are numerous side excursions to points of interest near the main lines of travel. In addition there are three supplementary routes from the Oberland to Lake Lucerne, by the Brünig, Susten, and Furca passes, in the last of which the St. Gotthard region is included.

The first chapter treats of that model of folded mountain structure, the Bernese Jura, than which there is no better introduction to the tectonics of the Alps. Following this are placed the regions intermediate between the Jura and the high Alps—Bern, the Lake of Thun, and Interlaken. In the Oberland proper the route visits in succession the well-known centers of attraction, Mürren, Wengern Alp, Grindelwald, Meiringen,

Grimsel Pass, Eggishorn, and Belalp—a circular tour around the great peaks of this group. Succeeding chapters describe the points of geologic interest from the Rhone valley to Bern by way of Kandersteg and Spiez and of the western portion of the range as far as Lake Geneva. In this itinerary the excursions have been planned for the pedestrian rather than the mountain climber, and by selecting various readily accessible viewpoints much of the wilds of the range can be studied without the labor and difficulties involved in penetrating into the heart of the mountains.

The booklet is well illustrated with many profiles of structure, numerous photographs and sketches, and a map of the route. Being almost identical in size with Baedeker's *Switzerland*, it fits readily into a coat pocket. At the end is a summary of the geologic literature bearing upon this portion of the Alpine chain.

R. T. C.

Guide to the Geology and Paleontology of the Schoharie Valley in Eastern New York. By AMADEUS W. GRABAU. (New York State Museum, *Bulletin No. 92*, 1906.) Pp. 75–387, 24 plates, 225 figures and geologic map.

The Schoharie Valley is a classic locality in the history of American stratigraphic geology, since in it and Albany County the first systematic study of the Paleozoic rocks of New York was begun. In this valley, near Schoharie village, lived the Gebhards, father and son, who between 1820 and 1835 worked out the succession of Silurian and Devonian strata in that region, collected fossils, and proposed stratigraphic names some of which, as, for example, Pentamerus and Tentaculite limestones, are still familiar to geologists.

As the title indicates, this work is designed as a guide to the geology and paleontology of the Schoharie Valley for the use of students and others interested in its fine stratigraphic sections, for which it has long been famous. Naturally, therefore, the stratigraphy of the Schoharie region is minutely described, four chapters, comprising 150 pages of the *Bulletin*, being devoted to it. In these chapters the nineteen geological stages of that region, which range from the Lorraine of the Lower Silurian to the Catskill of the Upper Devonian, are fully described, together with the more characteristic fossils which are figured.

Chapters 5 and 6 are devoted to a description of characteristic sections in the Schoharie region and the Helderbergs, and Dr. Grabau has not confined himself simply to the sections which he has studied, but has quoted freely from the works of former students. It should also be stated that

he has fully credited the material derived from such sources, which is in marked contrast to the custom of some other geologists who have in recent years published descriptions of sections located in this area. While these chapters will not be so popular with the general reader, for the student of ability they will, perhaps, prove the most valuable of the entire book. Chapter 7 contains lists of fossils found in the various formations of the Schoharie region which have, in part, been compiled from the lists of earlier geologists. The next chapter, which is devoted to the physiography, gives an account of Howe's and Ball's caves. The ninth and final chapter considers the Schoharie region in its relation to man, and gives a full account of the formations or deposits of economic value. At the close of the work is an eight-page glossary of technical terms. The book is profusely illustrated by excellent plates of geological scenery, numerous figures of geological structure and fossils. A pocket contains a geologic map of the Schoharie and Cobleskill Valleys, on which are represented the following thirteen geological divisions, listed in ascending order, viz.: Lorraine shale, of Lower Silurian age; Brayman shale, Cobleskill dolomite, Manlius and Rondout dolomite and limestone, of Upper Silurian age; Coeymans limestone, New Scotland shale, Becraft limestone, Oriskany quartzite, Esopus grit, Schoharie grit, and Onondaga limestone, of Lower Devonian age; and the Marcellus shale and Hamilton formation, of Middle Devonian age. It will be readily seen that there is a long list of formations available for study which in the high and steep hills bordering the Schoharie Valley and in the Helderberg escarpment are admirably exposed.

The early work of Eaton in Albany County and of the Gebhards in the Schoharie Valley brought to the Helderbergs and the valley at an early date such famous geologists as Lyell, James Hall, and Louis Agassiz. In later years other professors from Harvard, Yale, Columbia, Cornell, Union, and other institutions have brought their students to this beautiful and classic ground. Now with this admirable *Guide* at hand this region should become a veritable Mecca for geologists. Students of the science are certainly under great obligations to Dr. Grabau for the preparation of this excellent handbook, and to Dr. John M. Clarke, New York's efficient and scholarly state geologist, for its publication in a most attractive and interesting form.

C. S. PROSSER

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